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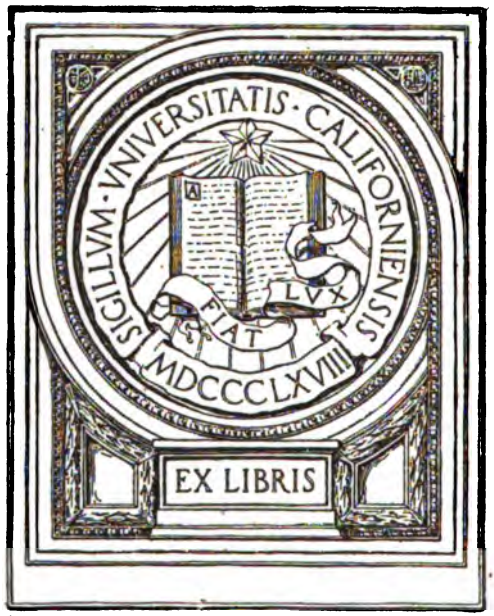

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

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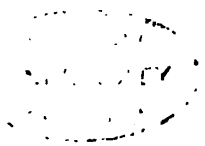
PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1901 *TO NOVEMBER* 1902.

VOL. LXII.



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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXII. NOVEMBER 8, 1901. No. 1

Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

Professor W. W. Campbell, Director of the Lick Observatory, San José, California, U.S.A.;
Professor J. Scheiner, Astrophysical Observatory, Potsdam, Germany; and
M. Ch. Trépied, Director of the Observatory, Algiers,

were balloted for and duly elected Associates of the Society.

Spencer Lavington Fletcher, 38 Lammas Park Road, Ealing, W.; and
Professor Monroe B. Snyder, Director of the Observatory, Philadelphia, Pa., U.S.A.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Ashton Charles Allen, 34 Kensington Palace Mansions, De Vere Gardens, W. (proposed by Rev. C. D. P. Davies);
John Hind Bell, *Nautical Almanac* Office, 3 Verulam Buildings, Gray's Inn, W.C. (proposed by A. M. W. Downing);
Walter Ernest Besley (H.M. Civil Service), 75 The Chase, Clapham Common, S.W. (proposed by F. W. Levander);

James Henry Booth, F.R.G.S., Schoolmaster, 32 Sunny Road, Southport (proposed by William Banks);

Arthur Thomas Cooper, A.M.Inst.E.E., Rivernook, De Montford Island, Reading (proposed by C. Hutchinson);

Joseph Alfred Hardcastle, 38 Eaton Square, S.W. (proposed by H. H. Turner);

Charles Sumner Howe, Ph.D., Professor of Astronomy, Case Observatory, Cleveland, Ohio, U.S.A. (proposed by Ambrose Swasey);

William Gylby Hutchinson, Rock Lodge, Roker, Sunderland (proposed by C. Hutchinson);

G. F. Johns, Perth Observatory, Western Australia (proposed by W. E. Cooke);

James William Lowber, M.A., Sc.D., Ph.D., LL.D., F.R.G.S., F.R.Met. Soc., 113 East 18th Street, Austin, Texas, U.S.A. (proposed by Captain M. C. Hepworth);

H. Krauss Nield, Thorold Grove, Sale, Cheshire (proposed by Samuel Chatwood);

Captain Michael Joseph O'Sullivan, Board of Trade Surveyor, 66 Fern Grove, Hartington Road, Sefton Park, Liverpool (proposed by H. G. Quirk);

Charles Tallent Spencer, A.M.Inst.C.E., La Quinta, Lyon Road, Harrow (proposed by A. G. Fowler); and

Rev. Charles Lakeman Tweedale, M.A., The Vicarage, Weston, near Ottley (proposed by R. Wilding).

One hundred and ninety-one presents were announced as having been received since the last meeting, including amongst others :—

Tycho Brahe, De Nova Stella (facsimile edition), presented by the R. Academy of Sciences, Copenhagen; Harvard Annals, vol. 28, part 2 (spectra of bright southern stars), presented by the Observatory; Lick Observatory Publications, vol. 5 (Hussey's measures of double stars), presented by the Observatory; Observations of the total eclipse of 1898 January 22, presented by Sir N. Lockyer; Atlas photographique de la lune, par MM. Loewy et Puiseux, presented by the Paris Observatory; Carte photographique du Ciel (22 charts), presented by the Paris Observatory; Annals of the Astrophysical Observatory of the Smithsonian Institution, vol. 1, presented by the Institution; Photographs of the great Comet of 1901, presented by the Perth Observatory, Western Australia.

Note respecting the Printing of Tabular Matter in the Society's Publications.

The Secretaries wish to draw the attention of Fellows who submit papers for publication in the *Memoirs* or *Monthly Notices* to the importance of drawing up tabular matter so as to fit the size of page as nearly as possible. Care in this respect will avoid the necessity which has sometimes arisen of printing tables the wrong way of the page. For example, a convenient form in which observations of double stars may be printed in the *Memoirs* will be found in *Mem.* vol. liii. pp. 294–307, and similarly for the *Monthly Notices* in *M.N.* vol. lxi. pp. 486–500. The form in the *Monthly Notices* may be taken as showing the maximum number of columns which can be printed on a page. As a rule, notes are best printed at the bottom of the page or at the end of a paper.

[SECRETARIES.]

Determination of Dr. Küstner's Magnitude Equation from Comparison of his Meridian Observations in Zones +24° to +27° with Measures of Photographic Plates taken at the University Observatory, Oxford. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. Dr. F. Küstner, Director of the Bonn Observatory, has embarked on a fine piece of work which he describes in the following terms: the formation of a catalogue of a number of stars of all magnitudes from the 4th to the 10th, uniformly distributed over the sky, reduced to the system of the Fundamental Catalogue of the *Astronomische Gesellschaft*, special attention being given to the determination and elimination of the magnitude equation in both R.A. and declination, and both of the fundamental catalogue and of the observer himself. Two parts of this work have already appeared.* The first gives a catalogue of 4,070 stars in zones 0° to +18°, and the second a catalogue of 4,292 stars in zones +18° to +36°. The zones under survey at the University Observatory, Oxford, as part of the astrographic chart work extend from +24° to +32° (plate centres +25° to +31°), and the zones with centres +25° +26° +27° are complete, while those with centres +28° and +29° will probably be completed by the end of this year (thirty plates are yet unfinished). There is thus considerable material for

* *Veröffentlichungen der königl. Sternwarte zu Bonn*, Nos. 4 and 5.

comparison with Dr. Küstner's observations already, though a complete comparison cannot be made for a year or two. Since Dr. Küstner is directing special attention to the magnitude equation, which he investigates by the method of screens (cutting down the light of the bright stars for some transits and leaving it unobscured in others), it is of interest to give at once the totally independent determination afforded by photographic measures, which can be made with very little trouble.

2. In former papers (*Monthly Notices*, vol. lvii. p. 473, and vol. lx. p. 3) the magnitude equation of the Cambridge meridian observations was determined by comparison with Oxford photographic measures. The variation per magnitude was $0^s{\cdot}023$ for stars brighter than magnitude 8·0, but much more rapid (about $0^s{\cdot}100$) for fainter stars. In a note to the second paper (vol. lx. p. 11) it was stated that if the photographic method of determining magnitude equation were accepted as correct, the screen method seemed liable to underestimate the amount of the equation owing to difficulty in assigning the photometric value of the screen. It would have been interesting if the present comparison could have thrown further light on this point; but, unfortunately for this particular purpose, Dr. Küstner's magnitude equation is very small—practically zero. He obtains coefficients in R.A. of opposite signs in the two volumes published: for stars in zones 0° to +18° the result is $+0^s{\cdot}0070$; for zones +18° to +36° the result is $-0^s{\cdot}0041$; and it may be added that before beginning this work he got from the Victoria comparison stars the value $-0^s{\cdot}0040$. The result obtained from the subjoined comparison is $+0^s{\cdot}009$.

3. The comparison was effected as follows. In the course of the ordinary work at Oxford those stars which have been observed on the meridian at Cambridge, as part of the great catalogue of the *Astronomische Gesellschaft*, are used to get the plate constants. These being obtained, the residuals for the individual stars, in the sense Oxford—Cambridge, are entered in ledgers; and the mean of these residuals (for two or more separate plates as the case may be) is for the present purpose taken as the correction to the Cambridge place. The Cambridge places are given in the original catalogue for epoch 1875·0, but for use in our work they have been brought up to 1900·0, so that a comparison with Küstner (1900·0) is easily made. Adding then Oxford—Cambridge to Cambridge—Küstner we get Oxford—Küstner. The Cambridge places are thus nearly, but not quite, eliminated. Their influence remains in the means for all stars on a plate; if there were, for instance, a systematic error depending on R.A. running through the Cambridge Catalogue, this would remain in the Oxford photographic places. But since stars of all magnitudes would be equally affected this would not matter for our present purpose. The differences Oxford—Küstner for zones +24° to +27°, formed in this way, were grouped according to magnitude (as given by Küstner) and means taken as below. It

should be particularly remarked that *no observations made with screens were included in the comparison*, which is thus altogether independent of screens.

Comparison of Oxford (Photographic) – Küstner (Visual) Zones + 24° to + 27° only.

Limits of Mag.	Adopted Mean Mag.	No. of Stars.	Oxford – Küstner. R.A. s	Oxford – Küstner. Dec. "	O – K Corrected. R.A. s	O – K Corrected. Dec. "
7·1 to 8·0	7·5	49	+0·138	−0·08	+0·014	+0·11
8·1 to 8·5	8·3	52	+ ·116	−0·24	−0·015	−0·13
8·6 & 8·7	8·65	35	+ ·132	−0·22	−0·003	−0·15
8·8 & 8·9	8·85	44	+ ·132	−0·05	−0·004	0·00
9·0 & 9·1	9·05	68	+ ·132	+0·02	−0·006	+0·04
9·2	9·2	44	+ ·136	0·00	−0·004	+0·01
9·3	9·3	37	+ ·148	+0·08	+0·007	+0·07
Over 9·3	9·6	38	+ ·156	+0·04	+0·013	0·00
Means ...	8·8	46	+ ·136	−0·05		

4. It is clear that the magnitude equation is very small, especially in R.A. If we assume a formula

$$a + b\,(\text{mag.} - 8{\cdot}8)$$

to represent the differences, and find a and b by "least squares," regarding the means for the groups as of equal weight, we get numerical values for b as follows :—

in R.A. $+0^{s}{\cdot}009$ in Dec. $+0''{\cdot}11$

Küstner's values are, from zones $+18°$ to $+36°$ (in which the zones $+24°$ to $+27°$, which form the basis of the above comparison, are included)

in R.A. $-0^{s}{\cdot}0041$ in Dec. $+0''{\cdot}064$

while from zones $0°$ to $+18°$ he got the results

in R.A. $+0^{s}{\cdot}0070$ in Dec. $+0''{\cdot}105$

In the columns of the above table headed "O – K corrected" the residuals of the previous columns are given after subtracting $+0^{s}{\cdot}136 + (m - 8{\cdot}8)\,0^{s}{\cdot}009$ in R.A. and $-0''{\cdot}05 + (m - 8{\cdot}8)0''{\cdot}11$ in Decl.

5. As indicating the general accuracy of both sets of results (Küstner and Oxford), the following table showing the number of differences of various values may be interesting.

Individual Value of Oxford—Küstner.

In R.A.				In Decl.			
Value of Diff.	No. of Cases.	Value of Diff.	No. of Cases.	Value of Diff.	No. of Cases.	Value of Diff.	No. of Cases.
s		s		"		"	
−0·01	4	+0·16	25	−2·0	1	+0·1	22
0·00	1	+0·17	23	−1·9	2	+0·2	19
+0·01	2	+0·18	18	−1·3	1	+0·3	26
+0·02	3	+0·19	15	−1·2	5	+0·4	17
+0·03	3	+0·20	11	−1·0	2	+0·5	20
+0·04	8	+0·21	8	−0·9	9	+0·6	9
+0·05	6	+0·22	7	−0·8	8	+0·7	7
+0·06	7	+0·23	5	−0·7	19	+0·8	5
+0·07	15	+0·24	3	−0·6	15	+0·9	5
+0·08	19	+0·25	6	−0·5	20	+1·0	5
+0·09	16	+0·26	0	−0·4	29	+1·1	2
+0·10	25	+0·27	1	−0·3	20	+1·2	4
+0·11	17	+0·28	1	−0·2	35	+1·3	4
+0·12	24	+0·29	0	−0·1	24	+1·4	1
+0·13	34	+0·30	2	0·0	31		
+0·14	28	+0·31	1				
+0·15	28	+0·34	1				

General Conclusion.

Dr. Küstner's magnitude equation as determined by a comparison with Oxford photographic measures is in substantial agreement both in R.A. and Decl. with that found by him, using the method of screens; but the quantities are too small to settle the question whether the screen method is apt to give values which should be multiplied by a factor, as suggested in a former paper.

On Periodic Orbits in the Neighbourhood of Centres of Libration.

By H. C. Plummer, M.A.

1. It is well known that there are five exact solutions of the problem of three bodies in each of which the bodies preserve an unvarying configuration which revolves with a uniform velocity. It is also known that when the third body is of infinitesimal mass compared with the other two, it can describe small periodic orbits in the vicinity of the points where exact solutions exist. These points have been given by Gyldén the name of *centres of libration*, and a body describing an orbit of the kind indicated

has been called by Professor Darwin an *oscillating satellite*. Such orbits have been investigated recently by Dr. Charlier in a very interesting and suggestive paper.* The method which he has adopted is extremely simple and familiar, and several of his results had been given previously by Professor G. H. Darwin, in whose work the subject only presented itself incidentally, and by Mr. Moulton in his paper on the origin of the *Gegenschein*.† I wish here to discuss some of Dr. Charlier's results in a slightly more general manner. It is true that the direction in which greater generality can be secured without increased difficulty will lead us away from the problem of three bodies. But it is possible that the conclusions which follow will prove interesting in themselves, that they may conceivably find an application to some physical problem of a totally different order, and that something more may be learnt with regard to their general character and limitations. At any rate any attempt to draw wider attention to a subject which presents such a promising field for investigation may perhaps be justified.

2. Let us consider the motion of a particle in a rotating field of force. The forces are to be derived from a complete potential function Ω, the precise form of which need not at present be defined except as some uniform function of x and y, the coordinates referred to rotating axes. Then the equations of motion of the particle may by a suitable choice of units be expressed in the form

$$\ddot{x}-2\dot{y}=\frac{\partial\Omega}{\partial x}$$

$$\ddot{y}+2\dot{x}=\frac{\partial\Omega}{\partial y}$$

As is well known these apply in particular to the motion of a body of infinitesimal mass under the influence of two bodies revolving in circles about their centre of gravity. Now let a centre of libration be defined as a point whose coordinates (x, y) satisfy the relations

$$\frac{\partial\Omega}{\partial x}=\frac{\partial\Omega}{\partial y}=0$$

At such a point equilibrium, which may be either stable or unstable, is possible. Now let a surface be defined by the equation $z=\Omega$, and let the ordinary notation be adopted, viz.

$$\frac{\partial z}{\partial x}=p \qquad \frac{\partial z}{\partial y}=q$$

$$\frac{\partial^2 z}{\partial x^2}=r \qquad \frac{\partial^2 z}{\partial x\partial y}=s \qquad \frac{\partial^2 z}{\partial y^2}=t$$

* *Meddelanden från Lunds Astronomiska Observatorium*, No. 18.
† *Astr. Journ.*, No. 483.

Now if in the equations of motion we substitute $x+\xi$, $y+\eta$ for x and y and consider (x, y) a fixed point, we obtain

$$\ddot{\xi}-2\dot{\eta}=\frac{\partial\Omega}{\partial x}+\xi\frac{\partial^2\Omega}{\partial x^2}+\eta\frac{\partial^2\Omega}{\partial x\partial y}+\cdots$$

$$\ddot{\eta}+2\dot{\xi}=\frac{\partial\Omega}{\partial y}+\xi\frac{\partial^2\Omega}{\partial x\partial y}+\eta\frac{\partial^2\Omega}{\partial y^2}+\cdots$$

Hence if (x, y) is a centre of libration so that $p=q=0$ and if we neglect second and higher powers of ξ and η we may write

$$\ddot{\xi}-2\dot{\eta}=r\xi+s\eta$$
$$\ddot{\eta}+2\dot{\xi}=s\xi+t\eta$$

Then $\xi=Ae^{\lambda t}$, $\eta=Be^{\lambda t}$ satisfy the equations provided

$$A(\lambda^2-r)-B(2\lambda+s)=0$$
$$A(2\lambda-s)+B(\lambda^2-t)=0$$

i.e. $$(\lambda^2-r)(\lambda^2-t)+4\lambda^2-s^2=0$$

or $$\lambda^4+\lambda^2(4-r-t)+rt-s^2=0$$

Stability depends on the nature of the roots of this equation.

3. Now let ρ_1, ρ_2 be the principal radii of curvature at the corresponding point of the surface $z=\Omega$. Since $p=q=0$ they are the roots of the quadratic

$$(rt-s^2)\rho^2+(r+t)\rho+1=0$$

Hence we may rewrite the preceding equation in λ^2 in the form

$$\lambda^4+\lambda^2\left(4+\frac{1}{\rho_1}+\frac{1}{\rho_2}\right)+\frac{1}{\rho_1\rho_2}=0$$

By means of this equation the conditions of stable equilibrium at a centre of libration are immediately connected with the properties of the surface $z=\Omega$. For perfect stability it is necessary that both values of λ^2 shall be real and negative. Hence we must in the first place have both ρ_1 and ρ_2 of the same sign, the surface synclastic at the point, and z a real maximum or a real minimum. The second condition is that

$$4+\frac{1}{\rho_1}+\frac{1}{\rho_2}>-\frac{2}{\sqrt{\rho_1\rho_2}}$$

If z is a maximum, ρ_1 and ρ_2 are positive, and the condition is necessarily fulfilled. If z is a minimum, ρ_1 and ρ_2 are negative, and the condition may be written

$$\frac{1}{+\sqrt{-\rho_1}}+\frac{1}{+\sqrt{-\rho_2}}<2$$

Thus, while in a stationary field of force equilibrium is stable where the force function is a maximum only, in a rotating field the function Ω, which it must be remembered includes the rotation potential, may be either a maximum or a minimum, provided in the latter case a certain inequality is satisfied. On the other hand we may have one value of λ^2 negative and the other positive. This corresponds to curvatures of opposite sign or an anticlastic point on the Ω surface. In this case a mode of periodic motion is combined with an unstable mode which must sooner or later prove fatal to the stable form. Neither purely positive nor imaginary values of λ^2 can be admitted in a search for periodic orbits.

4. I consider first the far more interesting case in which two periodic solutions are possible. Let us assume

$$\xi = h\cos(mt-\alpha) \qquad \eta = k\cos(mt-\beta)$$

as a periodic solution of the equations

$$\ddot{\xi} - 2\dot{\eta} = r\xi - s\eta$$
$$\ddot{\eta} + 2\dot{\xi} = s\xi + t\eta$$

The conditions obtained by substitution are

$$(r+m^2)\,h\cos\alpha + sk\cos\beta = -2mk\sin\beta$$
$$(r+m^2)\,h\sin\alpha + sk\sin\beta = \quad 2mk\cos\beta$$
$$(t+m^2)\,k\cos\beta + sh\cos\alpha = \quad 2mh\sin\alpha$$
$$(t+m^2)\,k\sin\beta + sh\sin\alpha = -2mh\cos\alpha$$

Hence we obtain directly

$$(r+m^2)\,h\sin(\alpha-\beta) = 2mk$$
$$sk\sin(\alpha-\beta) = -2mk\cos(\alpha-\beta)$$
$$(t+m^2)\;k\sin(\alpha-\beta) = \quad 2mh$$
$$sh\sin(\alpha-\beta) = -2mh\cos(\alpha-\beta)$$

which are equivalent to

$$h^2(r+m^2) = k^2(t+m^2)$$
$$s\tan(\alpha-\beta) = -2m$$
$$4m^2\operatorname{cosec}^2(\alpha-\beta) = (r+m^2)(t+m^2) = 4m^2+s^2$$

Hence the periodic orbit is obtained by combining two simple harmonic motions at right angles. These motions are characterised by a constant ratio of the amplitudes and a constant difference of phase for each centre of libration and assigned period. The orbits may be illustrated by Lissajou's figures for tuning-forks in unison. This is a very simple way of stating the

connection between the integration constants. The true arbitraries are, of course, the epoch and the scale of the orbit. Except for these the character of the orbits is absolutely determined by the nature of the field of force.

5. The equation of the orbit can be written down at once in the form

$$\frac{\xi^2}{h^2}+\frac{\eta^2}{k^2}-\frac{2\xi\eta}{hk}\cos(\alpha-\beta)=\sin^2(\alpha-\beta)$$

It will be found that an important distinction must be drawn in what follows, according as equilibrium corresponds to a maximum or minimum value of Ω. The latter case may be considered first. Then both r and t are positive, and we may put

$$c^2=h^2(r+m^2)=k^2(t+m^2)$$

and since

$$s(r+m^2)hk\sin^2(\alpha-\beta)=-4m^2k^2\cos(\alpha-\beta)$$

we have also

$$-hk\,.\,s\sec(\alpha-\beta)=c^2$$

The orbit becomes

$$(r+m^2)\xi^2+(t+m^2)\eta^2+2s\xi\eta=4m^2c^2/(4m^2+s^2)$$

and the axes and foci are given by

$$\frac{\xi^2-\eta^2}{r-t}=\frac{\xi\eta}{s}=-\frac{c^2}{4m^2+s^2}$$

The directions of the axes depend, then, on the form of the potential alone, and the major axis lies in the first and third quadrants if s is negative, in the second and fourth if s is positive. But for the surface $z=\Omega$

$$z+\delta z=\Omega+p\xi+q\eta+\tfrac{1}{2}(r\xi^2+2s\xi\eta+t\eta^2)+\ldots$$

or

$$2\delta z=r\xi^2+2s\xi\eta+t\eta^2$$

is the indicatrix corresponding to a centre of libration. The axes and foci are given by

$$\frac{\xi^2-\eta^2}{r-t}=\frac{\xi\eta}{s}=\frac{(2\delta z)^2}{s^2-rt}$$

and $s^2-rt=-\rho_1^{-1}\rho_2^{-1}$ is negative. Hence the major axes of the orbit and of the indicatrix are parallel. An alternative form of statement is that the axes of the orbit are parallel to the tangents to the lines of curvature at the corresponding point of the Ω surface.

6. The semi-axes a, b of the orbit are given by

$$\frac{1}{a^2}+\frac{1}{b^2}=(r+t+2m^2)\,(4m^2+s^2)\,/4m^2c^2$$

$$\frac{1}{a^2b^2}=(4m^2+s^2)^2/4m^2c^4$$

Hence a^2 and b^2 are the roots of the quadratic

$$(4m^2+s^2)^2\,x^2-(r+t+2m^2)\,(4m^2+s^2)c^2x+4m^2c^4=0$$

$$\therefore\ 2(4m^2+s^2)\,.\,x/c^2=r+t+2m^2 \pm\sqrt{\{4m^4+4m^2(r+t-4)+(r+t)^2\}}\,.$$

$$=r+t+2m^2\pm\sqrt{\{4(s^2-rt)+(r+t)^2\}}$$

$$=2m^2-\left(\frac{1}{\rho_1}+\frac{1}{\rho_2}\right)\pm\left(\frac{1}{\rho_1}-\frac{1}{\rho_2}\right)$$

We may therefore write

$$a^2=c^2\left(m^2-\frac{1}{\rho_1}\right)/(4m^2+s^2)$$

$$b^2=c^2\left(m^2-\frac{1}{\rho_2}\right)/(4m^2+s^2)$$

where ρ_1 is the numerically smaller of the two radii of curvature, for these are both negative. Accordingly the eccentricity e is given by

$$e^2=(\rho_2^{-1}-\rho_1^{-1})/(m^2-\rho_1^{-1})$$

and we notice that a circular orbit corresponds to an umbilic on the Ω surface.

7. We can now examine the initial conditions and the relation of our constant c to the constant C of the Jacobian integral

$$V^2=2\Omega-C$$

Let $(\xi_0.\ \eta_0)$ be the position at the time $t=0$. Then since

$$\xi=h\cos(mt-\alpha)\quad \eta=k\cos(mt-\beta)$$

we have

$$\xi_0=h\cos\alpha \qquad \eta_0=k\cos\beta$$

$$\dot{\xi}_0=mh\sin\alpha \qquad \dot{\eta}_0=mk\sin\beta$$

$$\therefore\ V^2=\dot{\xi}_0^2+\dot{\eta}_0^2=m^2(h^2+k^2)-m^2(\xi_0^2+\eta_0^2)$$

But

$$2\Omega=2\Omega_0+r\xi_0^2+t\eta_0^2+2s\xi_0\eta_0$$

where Ω_0 is the value of Ω corresponding to the centre of libration. If $2\,\Omega_0=C_0$

$$C=C_0-m^2(h^2+k^2)+(r+m^2)\xi_0^2+(t+m^2)\eta_0^2+2s\xi_0\eta_0$$

Thus for a given value of $C-C_0$, ξ_0 and η_0 must satisfy the equation of a certain ellipse which can be no other than the orbit already found. Hence by comparison we find

$$\begin{aligned} C-C_0 &= 4m^2c^2/(4m^2+s^2)-m^2(h^2+k^2) \\ &= \frac{4m^2c^2}{4m^2+s^2} - \frac{m^2c^2(2m^2+r+t)}{(m^2+r)(m^2+t)} \\ &= m^2c^2(4-r-t-2m^2)/(4m^2+s^2) \end{aligned}$$

Now if m_1^2 and m_2^2 are the roots of the quadratic giving m^2

$$m_1^2+m_2^2=4-r-t$$

or

$$(2m_1^2+r+t-4)+(2m_2^2+r+t-4)=0$$

Hence $C-C_0$ clearly has opposite signs according to the period selected, that is, one period and one eccentricity correspond to an increase, and the other period and eccentricity to a decrease of the energy constant as compared with the value required for relative rest. Thus when stable equilibrium exists at a point where Ω is a minimum a given value of C determines the orbit uniquely. Dr. Charlier has noticed this in a particular case, but his proof is not of a general character. Another peculiarity is that one family of orbits is bounded by a set of "limiting curves," while the other is not.

8. The period of the orbit is $2\pi/m$. But the units have been so chosen that the period of rotation of the field of force is 2π. Therefore m may be defined as the ratio of the period of the rotating field to the synodic period of the orbit. The direction of motion is determined by the sign of

$$\begin{aligned} \xi\dot{\eta}-\dot{\xi}\eta &= -mhk\sin(\alpha-\beta) \\ &= -2m^2c^2/(4m^2+s^2) = -mab \end{aligned}$$

The angular momentum being negative, the orbits of both families are retrograde. If it is desired to write down the equation of an orbit in a form involving only the energy constant and quantities depending only on Ω, we are led to

$$\begin{aligned} (r+m^2)\xi^2+(t+m^2)\eta^2+2s\xi\eta &= 4(C-C_0)/(4-r-t-2m^2) \\ &= 4n(C-C_0) \end{aligned}$$

where

$$\begin{aligned} n^{-2} &= (4-r-t)^2-4(rt-s^2) \\ &= \left(\frac{1}{\rho_1}-\frac{1}{\rho_2}\right)^2+8\left(\frac{1}{\rho_1}+\frac{1}{\rho_2}\right)+16 \end{aligned}$$

It may be observed that it is the family of shorter period and smaller eccentricity which requires $C<C_0$.

9. Throughout §§ 5–8 it has been assumed that Ω is an absolute minimum at the centre of libration, and that accordingly

r and t are positive. This indeed happens to be the more interesting case in so far as the problem of three bodies is concerned because there the function Ω does not as a matter of fact possess a truly maximum value. But if Ω is an absolute maximum both r and t are negative. It will be convenient to denote the quadratic giving m^2 by $f(m^2)=0$. By substitution we obtain :

$$\left.\begin{aligned} f(-r) &= 4r-s^2 \\ f(-t) &= 4t-s^2 \end{aligned}\right\} \text{ are negative.}$$

$f(+\infty)$ is positive.

$f(0) = rt-s^2$ is positive.

Hence $-r$ and $-t$ separate the two positive roots m_1^2 and m_2^2. It is clear then that when Ω is a maximum m_1^2+r and m_1^2+t are negative, while m_2^2+r and m_2^2+t are positive if $m_2^2 > m_1^2$. Further, since

$$4-r-t-2m_1^2>0$$

we must have

$$4-r-t-2m_2^2<0$$

The orbits of shorter period, $2\pi/m_2$, are then similar to the orbits investigated in the case when Ω is a minimum, and they require that $C<C_0$. It is unnecessary to consider this family in further detail. It is only in the expressions for the semi-axes and eccentricity given in § 6 that it is necessary to interchange the two radii of curvature on account of the change of sign.

10. The family of orbits characterised by the longer period $2\pi/m_1$ possesses features, however, which require separate notice. In the place of $+c^2$ in the foregoing it is necessary to write $-c^2$. The formula given for the foci in § 5 shows that the major axis of a member of this family is at right angles to the corresponding axis of a short-period orbit. Further from § 8 it appears that the direction of motion is reversed and orbits of this family are direct. Since both c^2 and $(4-r-t-2m^2)$ have opposite signs in the two families we again have $C<C_0$. Consequently to any given value of C C_0 one orbit of each family corresponds. Indeed the Jacobian integral suffices to prove that $C \geqslant C_0$; for otherwise since $2\Omega_0 \nless 2\Omega$, the velocity of the displaced body would be imaginary. Hence the extension of Dr. Charlier's statement given in § 7 of this paper, must be restricted to cases where Ω is a minimum. The expressions given for the semi-axes in § 6 require no alteration, although the radii of curvature are positive : for $(m_1^2-\rho_1^{-1})$ and $(m_1^2-\rho_2^{-1})$ must be negative, and therefore $\rho_1^{-1} > \rho_2^{-1}$. The most interesting features of the family of orbits considered here are undoubtedly the change from retrograde to direct motion and the rotation of the major axis through a right angle.

11. When Ω is a maximum at the centre of libration, we have seen that two orbits correspond to one value of C. Again,

through a point two orbits can be drawn, and for these the values of C will in general be different. There are, however, points where two orbits of different families, and the same C meet. The orbits will be

$$(m_1^2+r)\xi^2+(m_1^2+t)\eta^2+2s\xi\eta=+4n(C-C_0)$$
$$(m_2^2+r)\xi^2+(m_2^2+t)\eta^2+2s\xi\eta=-4n(C-C_0)$$

Hence the locus of their intersection is

$$(m_1^2+m_2^2+2r)\xi^2+(m_1^2+m_2^2+2t)\eta^2+4s\xi\eta=0$$

Or since $m_1^2+m_2^2=4-r-t$

$$(4+r-t)\xi^2+(4-r+t)\eta^2+4s\xi\eta=0$$

This represents a pair of straight lines equally inclined to the axes of the orbit, and this is clear from the geometrical interpretation. For since C is the same for both orbits, the velocity in each at the point of intersection is the same. Hence the central perpendiculars on the tangents are equal, and it becomes evident that the above equation represents the locus of points where orbits of the two families intersect each other, and are equally inclined to the common radius vector. The locus will not be real unless

$$4s^2+(r-t)^2>16$$

i.e. $$\rho_1^{-1}\sim\rho_2^{-1}>4$$

And unless this condition is satisfied corresponding members of the two families will not intersect, so that one orbit will lie wholly within the other.

12. When at a centre of libration the function Ω is neither an absolute maximum nor an absolute minimum, oscillating satellites may still exist. In this case only one class of orbit is possible, and even this cannot be permanently stable. The equation $f(m^2)=0$ has one positive root and one negative. Since the equation

$$(2m_1^2+r+t-4)+(2m_2^2+r+t-4)=0$$

still holds, the first expression on the left hand must be positive if $m_1^2>0>m_2^2$. Hence $(2m_1^2+r+t)$ is positive, and since (m_1^2+r) and (m_1^2+t) must be of the same sign, if an elliptic orbit exists they must both be positive. Hence $C<C_0$, and the orbits possess the same general features as those of shorter period when Ω is a minimum. An unstable form of motion arises immediately if $C>C_0$, and this would be the case if motion in the periodic orbit be unduly retarded. We should infer that excess rather than defect of relative velocity would be favourable to the duration of quasi-stable motion, and this may have some bearing on the theory of the detention of meteorites in the neighbourhood of a centre of libration. We have seen that in general the direction

of the major axis of an orbit depends on the sign of s. An exception, of course, arises when $s=0$. This point happens to occur in the application of this paragraph, and may properly be considered in this connection. The formula given in § 5 for the foci of the orbit shows that the axes are parallel to the rotating axes of coordinates, and that the major axis is parallel or perpendicular to the line joining the controlling bodies, according as $r-t <$ or > 0. The only exception to this rule is in the case of long-period orbits corresponding to Ω a maximum, when the preceding inequalities are reversed.

13. About the special problem which suggested the foregoing slightly more general investigation, little need be said here, because it has been treated with some fullness by Dr. Charlier. But as I have had occasion to allude to the properties of the surface defined by the equation $z=\Omega$, it may not be out of place to consider briefly the nature of the surface determined by two bodies revolving in circles about their centre of gravity. The sum of the masses μ and ν is taken as the unit of mass, while the unit of time is such that the gravitational constant is unity and the unit of length the distance between the masses. Then the period $T=2\pi$, the angular velocity is unity, and we have

$$2\Omega=\mu\left(r_1^2+\frac{2}{r_1}\right)+\nu\left(r_2^2+\frac{2}{r_2}\right)$$

where r_1, r_2 are the distances from μ and ν respectively. Now Professor Darwin in his memoir * has drawn a typical series of the curves $2\Omega=$const., and if these be regarded not merely as a family of curves with an arbitrary parameter, but as a set of contour lines of a surface, we easily get a fair notion of the general character of that surface. Much indeed can be gathered from the simplest reasoning. At the two points where $r_1=r_2=1$, it is easy to prove that 2Ω is a true minimum and equal to 3. The familiar topographical illustration will be useful here. At each of these minimum points there is a valley. The function Ω becomes infinite at the points where the masses are placed, but for the present purpose these points may be represented by the summits of mountains. The contour lines, which are evidently symmetrical with respect to the line joining the masses, must rapidly approach a circular form as they recede from the centres of force and indicate rising ground in all directions outwards. The additional features of the surface must clearly be three passes, one running between the mountains and connecting the valleys, and two others beyond the two mountains and separating them from the ground rising in the distance. Each of the three passes has its highest point on the line of symmetry, and these three points correspond to the three collinear centres of libration. Here the Ω surface is anticlastic, and, as indeed is evident on dynamical grounds, stable equilibrium is out of the question.

* *Acta Math.*, t. xxi. p. 113.

14. Although there cannot be any doubt as to the nature of these points, yet it may be permissible to consider them from another point of view. In what follows the origin is taken at the centre of gravity of the revolving bodies, the latter always lying on the rotating axis of x. Since

$$2\Omega = \mu\left(r_1^2 + \frac{2}{r_1}\right) + \nu\left(r_2^2 + \frac{2}{r_2}\right)$$

we have

$$\frac{\partial\Omega}{\partial r_1} = \mu\left(r_1 - \frac{1}{r_1^2}\right); \quad \frac{\partial\Omega}{\partial r_2} = \nu\left(r_2 - \frac{1}{r_2^2}\right)$$

Also for the collinear centres of libration

$$y = 0; \quad \frac{\partial\Omega}{\partial x} = 0$$

or

$$\frac{\partial\Omega}{\partial r_1}\cdot\frac{\partial r_1}{\partial x} + \frac{\partial\Omega}{\partial r_2}\cdot\frac{\partial r_2}{\partial x} = 0$$

Moreover

$$\frac{\partial\Omega}{\partial y} = \frac{\partial\Omega}{\partial r_1}\cdot\frac{\partial r_1}{\partial y} + \frac{\partial\Omega}{\partial r_2}\cdot\frac{\partial r_2}{\partial y}$$

$$= \frac{y}{r_1}\cdot\frac{\partial\Omega}{\partial r_1} + \frac{y}{r_2}\cdot\frac{\partial\Omega}{\partial r_2}$$

Hence when $y = 0$

$$t = \frac{\partial^2\Omega}{\partial y^2} = \frac{1}{r_1}\cdot\frac{\partial\Omega}{\partial r_1} + \frac{1}{r_2}\cdot\frac{\partial\Omega}{\partial r_2}$$

$$s = \frac{\partial^2\Omega}{\partial x\partial y} = 0$$

We have now to treat separately the cases which arise.

(1) Between the masses μ and ν we have

$$r_1 + r_2 = 1; \quad \frac{\partial r_1}{\partial x} + \frac{\partial r_2}{\partial x} = 0$$

$$\therefore \frac{\partial\Omega}{\partial r_1} = \frac{\partial\Omega}{\partial r_2}$$

$$\therefore \mu\left(\frac{1}{r_1^2} - r_1\right) = \nu\left(\frac{1}{r_2^2} - r_2\right)$$

Hence clearly $r_1 > r_2$ if $\mu > \nu$. In this case

$$t = \left(\frac{1}{r_1} + \frac{1}{r_2}\right)\cdot\mu\left(r_1 - \frac{1}{r_1^2}\right)$$

and is negative, for $r_1 < 1$.

(2) Beyond the mass μ we have

$$r_2 = r_1 + 1 \; ; \; \frac{\partial r_1}{\partial x} = \frac{\partial r_2}{\partial x}$$

$$\therefore \frac{\partial \Omega}{\partial r_1} + \frac{\partial \Omega}{\partial r_2} = 0$$

$$\therefore \mu\left(\frac{1}{r_1^2} - r_1\right) = \nu\left(r_2 - \frac{1}{r_2^2}\right)$$

Hence clearly $r_1 < 1$. In this case

$$t = \left(\frac{1}{r_1} - \frac{1}{r_2}\right) \cdot \mu\left(r_1 - \frac{1}{r_1^2}\right)$$

and is negative because $r_1 < 1 < r_2$, and therefore the first factor is positive and the last negative. The proof that t is negative in the case of the centre of libration lying beyond the mass ν can be inferred from the latter, as there is no restriction on the ratio of the masses μ and ν. Now we have

$$r = \frac{\partial^2 \Omega}{\partial x^2} = \mu\left(1 + \frac{2}{r_1^3}\right) + \nu\left(1 + \frac{2}{r_2^3}\right)$$

which is necessarily positive. Hence always for the three points considered

$$rt - s^2 < 0$$

and therefore the two roots of the quadratic in m^2 are of opposite signs. I have thought it worth while to give a definite proof of this fact because on this point Dr. Charlier says: "That is what I have found through numerical calculation for different values of μ, an algebraic demonstration of this fact seeming to be somewhat complicated."

University Observatory, Oxford:
1901 *October* 1.

A New Method of Interpolation. By T. C. Hudson, B.A.

1. Bessel's interpolation formula is

$$u_n - u_0 = n\Delta'_{\frac{1}{2}} + \frac{n(n-1)}{1 \cdot 2} \frac{\Delta_0'' + \Delta_1''}{2} + \frac{n(n-1)(n-\frac{1}{2})}{1 \cdot 2 \cdot 3} \Delta_{\frac{1}{2}}''' + \frac{(n+1)n(n-1)(n-2)}{1 \cdot 2 \cdot 3 \cdot 4} \frac{\Delta_0^{iv} + \Delta_1^{iv}}{2} + \ldots \quad (1)$$

2. As it stands this formula is partially symmetrical with respect to the middle of the interval; but there is no symmetry

in the first three terms, namely, u_n, u_0 and $n\Delta'_{\frac{1}{2}}$, and the symmetry of the last three does not present itself obviously to the eye. If, however, we replace

$$\frac{u_0+u_1}{2}, \frac{1}{1\cdot 2}, \frac{\Delta_0''+\Delta_1''}{2}, \frac{1}{1\cdot 2\cdot 3\cdot 4}, \frac{\Delta_0^{iv}+\Delta_1^{iv}}{2}, \Delta'_{\frac{1}{2}}, \Delta'''_{\frac{1}{2}}, \tfrac{1}{2}-n, u_n$$

by M, M'', M^{iv}, Δ', Δ''', m, U_{+m}

equation (1) becomes

$$U_{+m} = M - (\tfrac{1}{4}-m^2)M'' + (\tfrac{1}{4}-m^2)(\tfrac{2}{4}-m^2)M^{iv} - \ldots$$
$$- m\Delta' + m(\tfrac{1}{4}-m^2)\frac{\Delta'''}{6} - \ldots$$

(a modification of Bessel's formula due, it appears, to Newton) which may be written

$$U_{+m} = [E]+[O]$$

where $$[E] = M-(\tfrac{1}{4}-m^2)M''+(\tfrac{1}{4}-m^2)(\tfrac{2}{4}-m^2)M^{iv}-\ldots$$

containing only *even* differences and *even* powers of m,

and $$[O] = -m\Delta'+m(\tfrac{1}{4}-m^2)\frac{\Delta'''}{6}-\ldots$$

containing only *odd* differences and *odd* powers of m.

In the E equation it will be seen that M takes its place naturally with M'', M^{iv}, &c., its coefficient obeying the same law as theirs, and that the original quantities may be justly regarded as belonging to the family of even differences.

3. Changing the sign of m, and observing that U_{-m} is merely u_{1-n}, we have

$$U_{-m} = [E]-[O].$$

By these substitutions we have now arrived at a pair of formulæ

$$\left\{\begin{array}{l} U_{+m} = [E]+[O] \\ U_{-m} = [E]-[O] \end{array}\right\} \quad \ldots\ldots \quad (2)$$

which possesses the practical, economic advantage of being symmetrical with respect to the middle of the interval.

4. The advantage consists in this, that when once [E] and [O] have been computed for the first half of the interval, and their sum has given the *first* half of the new quantities (u_n or U_{+m}), then their difference gives the *second* half without further computation. This means a saving of half the labour involved in a great part of the work of systematic interpolation. Moreover, the more new quantities we have to interpolate between the old data, the greater (relatively) becomes this economy. In particular, to take the opposite extreme, in the simplest case, that of "bisection," where we should want only midway quantities, we

observe that m, [O], and the difference between the formulæ (2) would all vanish together—likewise the economy.

But in the actual case of the work of deriving the Moon's hourly places for the *Nautical Almanac* from twelve-hourly data throughout a whole year, the degree of subdivision of the original interval into twelve new ones is so great that the aforesaid economy becomes an important consideration.

5. For this reason I found it worth while, a few years ago, to make new tables for the interpolation of the Moon's hourly R.A. and Dec., in which case (known variously as "interpolation to twelfths" and as "interval twelve") we have the following values :—

of $12n$	viz.	1	2	3	4	$5\rightarrow$		6
		11	10	9	8	$7\leftarrow$		
of $12m$	,,	± 5	± 4	± 3	± 2	$\pm 1\rightleftarrows$		0
of the coefficients of								
$\frac{\Delta'}{12}$ in [O]	,,	∓ 5	∓ 4	∓ 3	∓ 2	$\mp 1\rightleftarrows$		0
$\frac{1}{6}\frac{\Delta'''}{12^3}$ in [O]	,,	± 55	± 80	± 81	± 64	$\pm 35\rightleftarrows$		0
$-\frac{1}{144}\left(M''-\frac{317}{144}M^{iv}\right)$ in [E]	,,	-11	-20	-27	-32	$-35\rightleftarrows$	-36	

and of the residual coefficients of

$\frac{1}{2}\frac{M^{iv}}{12^3}$ in [E]	viz.	-33	-30	-9	$+16$	$+35\rightleftarrows$	$+42$	

6. With regard to these tabulated coefficients it may be noted

(*a*) That no other interpolation formula gives such simple coefficients as it stands, nor could it be made to do so by any other modification without seriously impairing the simplicity of treatment of the original differences, and also introducing additional sources of cumulative error.

(*b*) That the second coefficient of $\frac{M''}{144}$ is -20, *i.e.* the second coefficient of $\frac{\text{mean } \Delta''}{144}$ is -10. This is a most happy coincidence, and it means that the second member of the series of Δ'' corrections happens to be numerically identical with ten times the new middle δ'', so that we are practically getting two things at once, and we have an opportunity of condensing the corresponding table by making the second column do double duty by acting as vertical argument as well. There are other practical advantages of this coincidence which will appear later. Suffice it here to say

that it is the Δ'' table that has hitherto caused the most trouble in construction and in use, and that it is this very table which is hereby simplified.

(*c*) That with a view to (i) dispensing as often as possible with Δ^{iv} corrections (as such) without seriously impairing the simplicity of treatment of the original second differences, and (ii) at the same time minimising resulting error (whether individual or mean, neglected or corrected), I have selected the particular device (as in the above table of coefficients) of subtracting $\frac{317}{1725}$ of the mean Δ^{iv} from the mean Δ'', on the grounds that the resulting "residual Δ^{iv} corrections" are generally negligible, that their mean algebraical value throughout an interval is *zero*, and their maximum value is about half a thousandth of the original mean Δ^{iv}, so that these residuals may be tabulated in three or four lines only, and then never referred to except as a matter of fact when the Moon is near a maximum declination, and that declination is also a large one by reason of the position of the Moon's node. Other devices might have been chosen, but at the sacrifice of one or more of these practical advantages. Moreover, further pursuit of this same method (such as entrusting the broad fifth-difference effect to the third-differences) would on the whole in each case rather complicate than expedite the work.

7. In the tables, which are purely *additive*, only such information is given as is necessary and sufficient, (*a*) to produce the end figure of the new quantities, and (*b*) to enable the calculator to fill in the rest with ease. By this economy the tables are reduced to very small compass.

Comparisons of the Geocentric Places of Uranus, Neptune, and the Sun, calculated from Newcomb's Tables, with their Places calculated from Le Verrier's Tables, for the Year 1904. By A. M. W. Downing, D.Sc., F.R.S.

This paper is a continuation of one printed in *Monthly Notices*, vol. lix., No. 10. The *Nautical Almanac* for 1904 is the first in which Newcomb's Tables of *Uranus* and *Neptune* are used, and a comparison is made at convenient intervals throughout the year between the places there given for Greenwich noon and the corresponding places computed from those given in the *Connaissance des Temps* for 1904 for Paris noon.

I have also added a comparison of the Sun's places, deduced in the same manner, at intervals of eight days throughout the year.

URANUS, 1904.—*Corrections to Le Verrier's Tables.*

Day. 1904.	R.A. Time.	R.A. Arc.	Dec.	Day. 1904.	R.A. Time.	R.A. Arc.	Dec.
	s	"	"		s	"	"
Jan. 1	−·33	−4·5	+0·1	July 3	−·34	−4·7	0·0
Feb. 2	−·34	−4·7	0·0	Aug. 4	−·33	−4·5	+0·2
Mar. 1	−·36	−4·9	0·0	Sept. 1	−·34	−4·7	+0·1
Apr. 2	−·36	−4·9	0·0	Oct. 3	−·31	−4·2	+0·1
May 4	−·37	−5·1	+0·1	Nov. 4	−·31	−4·2	−0·1
June 1	−·36	−4·9	−0·1	Dec. 2	−·32	−4·4	−0·2

NEPTUNE, 1904.—*Corrections to Le Verrier's Tables.*

Day. 1904.	R.A. Time.	R.A. Arc.	Dec.	Day. 1904.	R.A. Time.	R.A. Arc.	Dec.
	s	"	"		s	"	"
Jan. 1	−·38	−5·3	−2·0	July 3	−·38	−5·3	−1·8
Feb. 2	−·41	−5·7	−1·8	Aug. 4	−·38	−5·3	−1·7
Mar. 1	−·41	−5·7	−1·9	Sept. 1	−·40	−5·6	−1·7
Apr. 2	−·39	−5·4	−1·9	Oct. 3	−·41	−5·7	−1·8
May 4	−·39	−5·4	−1·8	Nov. 4	−·41	−5·7	−1·9
June 1	−·38	−5·3	−1·7	Dec. 2	−·41	−5·7	−1·9

SUN, 1904.—*Corrections to Le Verrier's Tables.*

Day. 1904.	R.A. Time.	R.A. Arc.	Dec.	Day. 1904.	R.A. Time.	R.A. Arc.	Dec.
	s	"	"		s	"	"
Jan. 1	−·06	−0·8	−0·2	May 24	−·02	−0·3	+0·1
9	−·04	−0·6	−0·3	June 1	−·01	−0·1	+0·3
17	−·04	−0·6	−0·2	9	−·01	−0·1	+0·2
25	−·04	−0·6	−0·3	17	−·02	−0·3	+0·3
Feb. 2	−·03	−0·4	−0·2	25	−·02	−0·3	+0·2
10	−·03	−0·4	−0·3	July 3	−·02	−0·3	+0·2
18	−·03	−0·4	−0·4	11	−·03	−0·4	+0·3
26	−·03	−0·4	−0·3	19	−·02	−0·3	+0·3
Mar. 5	−·03	−0·4	−0·1	27	−·02	−0·3	+0·3
13	−·02	−0·3	−0·1	Aug. 4	−·02	−0·3	+0·2
21	−·03	−0·5	−0·2	12	−·02	−0·3	+0·2
29	−·03	−0·5	−0·1	20	−·03	−0·4	+0·3
Apr. 6	−·01	−0·1	0·0	28	−·02	−0·3	+0·2
14	−·02	−0·3	−0·1	Sept. 5	−·03	−0·4	+0·2
22	−·02	−0·3	0·0	13	−·04	−0·6	+0·3
30	−·01	−0·1	+0·1	21	−·04	−0·6	+0·3
May 8	−·02	−0·3	+0·2	29	−·04	−0·6	+0·1
16	−·01	−0·1	+0·2	Oct. 7	−·05	−0·7	+0·2

Day. 1904.	R.A. Time.	R.A. Arc.	Dec.	Day. 1904.	R.A. Time.	R.A. Arc.	Dec.
	s	″	″		s	″	″
Oct. 15	−·05	−0·7	+0·3	Nov. 24	−·06	−0·8	−0·1
23	−·06	−0·9	+0·1	Dec. 2	−·05	−0·7	−0·1
31	−·06	−0·9	0·0	10	−·06	−0·8	−0·1
Nov. 8	−·06	−0·9	0·0	18	−·07	−1·0	−0·2
16	−·07	−1·0	+0·1	26	−·05	−0·7	−0·3

Experimental Reduction of some Photographs of Eros made at the Cambridge Observatory for the Determination of the Solar Parallax. By Arthur R. Hinks, M.A.

1. The long series of photographs of the planet *Eros* which I obtained last winter with the new Sheepshanks equatorial of the Cambridge Observatory was very much interrupted by bad weather. My programme was to make four exposures on the planet every hour between 6^h E. and W.—the construction of the instrument precludes greater hour-angles—and, of each set of four, two were made following the stars and letting the planet trail, two following the planet and letting the stars trail. There was only one case of two consecutive nights clear, or nearly so, right through, viz. 1900 November 9 and 10, and the plates taken on these nights, when the planet was but little past opposition, and the parallax factor had become fairly large, were clearly indicated as the subject of preliminary and experimental reductions. The plates were to be centered for each night on the position of the planet at Berlin midnight, the epoch of Professor Millosevich's ephemeris; but, by an accident very fortunate for our present purpose, the plates on the 9th were set to a centering very near that proper to the 10th, and the mistake was discovered in time to use the same point for the latter plates, so that all the exposures to be here treated have approximately the same centering on the sky.

2. As many as twenty exposures were made on one plate, the displacement necessary between each being given to the plate-carrier on rectangular slides on the breach-piece of the telescope, not by displacement of the pointing of the telescope on the sky. There is an obvious advantage in this, that the centre of projection remains unchanged, and all the exposures can be made comparable by linear formulæ of reduction, which is not strictly the case when the pointing of the telescope is changed.

3. The stars on the plates whose meridian places are known are not very symmetrically distributed about the locus of the planet, and many of them are inconveniently bright. It was necessary to consider the possibility of a systematic error due to the trail of either stars or planet—the motion of the planet was

more than a second of arc per minute—and if this exists it is almost necessarily a function of the magnitude. I selected, therefore, fourteen comparison stars well distributed about the locus of the planet, and of magnitudes as nearly as possible equal to it. These fourteen stars were measured with the planet on each exposure, with the new measuring machine which I have recently described (*Monthly Notices*, 1901 May). I may take this opportunity of saying that in accuracy, rapidity, and pleasure of use the machine has more than come up to expectation.

4. *Search for a systematic error due to trail.*—Each set of four exposures was arranged thus :—

a . . 3^m, b . . 2^m, stars fixed ; c . . 3^m, d . . 2^m, planet fixed.

A preliminary comparison showed that for any exposure the differences $b-a$ and $d-c$ for the fourteen comparison stars varied only accidentally from a constant ; they could not be represented by a linear function of the coordinates of the stars ; that is to say, during the short intervals the variations in differential refraction, orientation, &c., were insensible. In all that follows I have used the means of pairs, $\frac{1}{2}(a+b)$ and $\frac{1}{2}(c+d)$, as single exposures.

Next, an examination of the differences $\frac{1}{2}\overline{c+d}-\frac{1}{2}\overline{a+b}$ gave a similar result ; they could not be represented by a linear expression. But they ought to show an effect of error due to trail varying with the magnitude—if this error exists, indeed, at all. To examine this point, four fainter stars, whose images were barely measurable, were added to the above list of fourteen and measured on all the plates. For each of thirteen sets of four exposures the differences $\frac{1}{2}\overline{c+d}-\frac{1}{2}\overline{a+b}$ were formed, their mean taken, and the values of mean—individual found. Then, taking the mean of the thirteen results for each star, we have :

	B.D.	Mean Residual.		B.D.	Mean Residual.
1	+54° 434	−2	10	+54° 449	+ 1
2	54 435	−3	11	53 444	+ 1
3	54 438	−1	12	54 451	− 1
4	54 439	−3	13†	54 454	− 1
5	54 442	−1	14†	Anon.	+11
6†	54 443	−2	15	Anon.	− 3
7	Anon.	0	16	54 459	− 2
8	54 445	−3	17†	53 449	+ 4
9	53 441	−1	18	54 461	− 1

It does not seem worth while to add the visual magnitudes. The four stars, photographically fainter, which were added to the original fourteen are distinguished by a dagger. The

quantities are in ten-thousandths of a réseau interval, so that 1=0″·017. There is evidently something peculiar about star No. 14; it may be a close double. Its large positive residuals have made nearly all the others negative. For the three other faint stars the mean residuals are −2, −1, +4. It seems to me that there is no evidence of error depending upon trail varying with the magnitude; that it would certainly do so if it existed at all; and that it is unlikely therefore that it exists as a constant error. I propose, however, to keep the two series—A, stars fixed, B, planet fixed—separate throughout the work. The four faint stars, 6, 13, 14, 17, have not been further employed.

5. *Probable error of a measure.*—Incidentally we may derive from this discussion, if we assume that the differences $b-a$, $d-c$, and $\frac{1}{2}\overline{d+c}-\frac{1}{2}\overline{b+a}$ are entirely accidental and free from the systematic error depending on trail, an estimate of the P.E. of a measure on a single-star disc, *including the real error of position of the apparent centre of the photographic image itself.* Each measure includes two settings on the star disc in each of two positions of the plate differing in orientation by 180°. The results are:—

	From $b-a$.	$d-c$.	$\frac{1}{2}\overline{d+c}-\frac{1}{2}\overline{b+a}$.
P.E. of a complete measure in ξ	$\pm^{B}$·00053	$\pm^{B}$·00065	$\pm^{B}$·00060
P.E. of a complete measure in η	± ·00048	± ·00052	± ·00043

0^{B}0001=0″·0175. We may take as the P.E. of a measure of one image in ξ ±0″·10, in η ±0″·08.

6. *Reduction of all the plates to standard.*—The fourteen symmetrically arranged comparison stars were selected to provide a strong means of comparing the plates *inter se*. Besides the symmetry of their arrangement, they had the advantage of near equality in magnitude to the planet. Two "zero" exposures were chosen, one for each series, A and B, taken near the meridian on November 10, and all the others were first made comparable with these zero exposures. Following Turner's method of comparison by linear formulæ, equations of condition were formed of the usual pattern:

$$a\xi+b\eta+c+\xi-\xi'=0$$
$$d\xi+e\eta+f+\eta-\eta'=0$$

and for each exposure the six constants were found to reduce it to compare with a zero exposure.

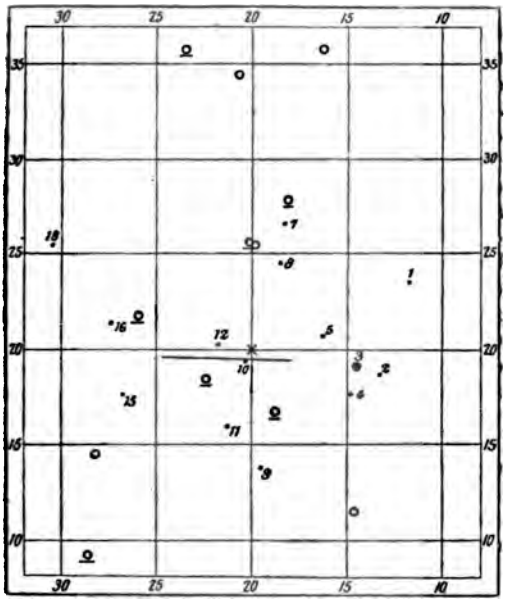
I have preferred to put aside for the present the well-disputed question whether the unsymmetrical part of the differential refraction should be calculated and applied numerically, and the six constants thereby reduced to four. The older method is shorter, and has some advantages in this first experimental work.

We have now each series of exposures comparable among

themselves, but affected still with the differential refraction and aberration, errors of orientation, scale-value, and centering of the zero exposures. On these two exposures only I have measured the images of all the stars on the plate which were to be found in the Harvard A. G. Zone Catalogue—there were scarcely enough stars in the Paris list, nor were they well distributed (see figure). The rectangular coordinates of these standard stars were computed for 1900·0 with assumed centre of plate

$$\alpha \quad 1^h\,57^m\,8^s \qquad \delta + 54^\circ\,22'{\cdot}0$$

and the six constants to reduce each zero exposure to standard were found as above.



Centre of plate (1900·0) α $1^h\,57^m\,8^s$ $\delta + 54^\circ\,22'{\cdot}0$.
• Comparison star. ——— Path of planet.
o Standard star; underlined o if in Paris list.
Half scale. Every fifth R. line only shown. 5R. = 14′·6.

The reduction of all the exposures to standard for 1900·0 proceeded, therefore, in two steps:

(1) Each exposure was reduced to the zero of its series by the aid of constants derived from the fourteen comparison stars.

(2) All were then reduced from zero to standard by the constants derived from the thirteen meridian standard stars (of which only two had served also as comparison stars).

The advantages of this double procedure seem to me to be as

follows:—In addition to the fact that the comparison stars are well distributed, and nearly equal to the planet in magnitude, we have the further advantage that there is no question of meridian places in the first step. The exposures are made comparable with one another by a process that may be considered final. No revision of meridian places can affect it. On the other hand, the reduction from zero to standard depends on the accuracy of the coordinates of the standard stars calculated from their meridian places; it may well have to be revised when better places are available. When this is done there will be only two sets of equations to solve again, instead of twenty-six.

I do not, however, anticipate that any revision of meridian places will seriously alter my constants for the reduction to standard, except perhaps the errors of centering c and f, which will be affected by the systematic difference between the fundamental systems of Auwers and Newcomb. The average residuals in the reduction of the thirteen standard stars are in ξ 0″·52 and in η 0″·44, which speaks well for the original accuracy of the Harvard places, affected as they are now by unknown proper motions for about twenty-five years.

7. *Search for evidence of the effect of atmospheric dispersion.*—The possibility of systematic error due to atmospheric dispersion is an objection that will be alleged against the determination of the solar parallax by photography. To this may be added in the present case the possibility of variable distortion due to flexure of the plane mirror of the Cambridge equatorial varying with the hour-angle. The two effects may here be included in the category "hour-angle error" as used by Kapteyn. It is possible to find in the reduction of all the exposures to a zero near the meridian a little evidence on this matter. In series A I have taken six exposures, three on each side of the meridian, and formed for each star the differences of the reduced values of ξ from the values on the zero exposure. They are given in the following table, the unit as before being the ten-thousandth of a réseau interval.

	East.			West.			
Hour-Angle.	$-4^h{\cdot}9$.	$-4^h{\cdot}0$.	$-2^h{\cdot}9$.	$+2^h{\cdot}9$.	$+4^h{\cdot}0$.	$+4^h{\cdot}9$.	$\frac{1}{2}(\Sigma W-\Sigma E)$.
Star 1	0	− 5	− 3	+ 2	0	+ 3	+ 4
2	+ 5	− 2	− 9	− 5	+ 3	+ 2	+ 3
3	− 4	+ 6	+ 2	+10	+ 4	+ 1	+ 4
4	− 1	+ 4	+ 7	+ 2	− 4	+ 3	− 3
5	+ 2	+ 1	+ 4	+ 5	+ 2	+ 6	+ 2
7	−12	−11	−13	−11	−12	−14	0
8	+ 2	+ 1	0	− 2	− 3	− 2	− 3
9	+ 8	+ 6	+11	0	+ 9	0	− 5
10	− 6	−11	−11	+ 5	− 4	+ 2	+10
11	+ 4	0	+ 2	+ 1	+ 2	+12	+ 3

	East.			West.			
Hour-Angle.	$-4^h\cdot9$.	$-4^h\cdot0$.	$-2^h\cdot9$.	$+2^h\cdot9$.	$+4^h\cdot0$.	$+4^h\cdot9$.	$\frac{1}{2}(\Sigma W-\Sigma E)$.
Star 12	+ 1	− 7	+ 4	− 1	+ 1	− 7	− 2
15	− 5	+ 4	− 7	−11	− 11	−13	− 9
16	0	− 4	+ 7	+ 7	+10	+ 1	+ 5
18	+ 8	+17	+ 5	− 1	+ 2	+ 5	− 8

If a star is extra blue its ξ is increased W. and diminished E.; the above residuals are algebraically diminished W. and increased E., so that the value of W.—E. (which is independent of the errors of measurement on the zero plate, except in so far as they affect the constants of reduction) is negative for an extra blue star. Taking the P.E. of a single measure in ξ as 6, the probable value of a quantity in the last column, allowing a little for accumulated errors in the reduction to zero, will be about 4—it must be remembered that each residual represents the mean of two exposures. Of the fourteen quantities in the last column, five are above 4, two equal to it, and seven below 4. There is, therefore, no indication that these quantities are other than purely accidental. The evidence is slight, but it is at least in the right direction.

8. *Reduced measures of the planet.*—The following table contains the mean epoch of exposure, expressed in decimals of a day from Berlin mean noon—called afterwards T+ΔT—the measured coordinates of the planet (means of *a* and *b* or of *c* and *d*), the same reduced to zero, and then to standard, and finally these last referred to the centre of the plate (20·0 20·0) as origin, and multiplied by the constant ·00085221 to express them in terms of the radius of projection.

TABLE I.

Measures of the planet.

	Series A. d.	Measures. ξ and η	Red. to Zero.	Red. to Standard.	In parts of Radius.
1	Nov. 9·552382	24·8337	24·6146	24·5935	+·00391463
		19·9144	19·7026	19·6764	−·00027578
2	·605387	24·4737	24·2663	24·2453	+·00361789
		19·9812	19·6846	19·6564	−·00029282
3	·649279	24·2036	23·9821	23·9612	+·00337577
		20·1298	19·6663	19·6365	−·00030978
4	·688555	23·9549	23·7352	23·7144	+·00316545
		20·1703	19·6461	19·6149	−·0003281
5	·729413	23·7058	23·4828	23·4621	+·00295044
		20·2200	19·6207	19·5880	−·00035111
6	10·277103	20·2625	20·2907	20·2704	+·00023044
		19·8577	19·5107	19·4596	−·00046053

	Series A. d.	Measures. ξ and η	Red. to Zero.	Red. to Standard.	In parts of Radius.
7	Nov. 10·317877	20·0017	20·0315	20·0112	+ ·00000954
		19·7320	19·5137	19·4612	− ·00045917
8	·356861	19·7636	19·7814	19·7611	− ·00020359
		19·6065	19·5121	19·4581	− ·00046181
9	·464122	19·0770	zero	19·0568	− ·00080380
		19·4933	exposure	19·4353	− ·00048124
10	·515599	18·9717	18·7358	18·7157	− ·00109449
		19·4730	19·4724	19·4124	− ·00050076
11	·565637	18·6214	18·4073	18·3873	− ·00137436
		19·5340	19·4453	19·3834	− ·00052547
12	·605862	18·3782	18·1460	18·1261	− ·00159696
		19·6375	19·4182	19·3548	− ·00054976
13	·650159	18·0889	17·8614	17·8417	− ·00183932
		19·7751	19·3849	19·3199	− ·00057959
	Series B.				
1	Nov. 9·556968	24·6744	24·4636	24·5632	+ ·00388880
		19·9127	19·6972	19·6746	− ·00027730
2	·609456	24·3153	24·1187	24·2184	+ ·00359496
		19·9880	19·6793	19·6547	− ·00029427
3	·653376	24·0454	23·8368	23·9366	+ ·00335481
		20·1384	19·6605	19·6343	− ·00031165
4	·693284	23·7892	23·5845	23·6844	+ ·00313988
		20·1689	19·6388	19·6112	− ·00033134
5	·733597	23·5449	23·3372	23·4372	+ ·00292922
		20·2229	19·6170	19·5879	− ·00035120
6	10·281374	20·1128	20·1415	20·2420	+ ·00020623
		19·8306	19·5071	19·4598	− ·00046036
7	·322405	19·8471	19·8811	19·9815	− ·00001577
		19·7276	19·5089	19·4601	− ·00046011
8	·361507	19·6090	19·6310	19·7314	− ·00022890
		19·6030	19·5080	19·4577	− ·00046215
9	·468533	18·9275	zero	19·0280	− ·00082835
		19·4876	exposure	19·4333	− ·00048295
10	·519523	18·8336	18·5904	18·6910	− ·00111554
		19·4762	19·4669	19·4107	− ·00050221
11	·569935	18·4646	18·2580	18·3588	− ·00139865
		19·5361	19·4384	19·3803	− ·00052811
12	·610161	18·2281	17·9975	18·0984	− ·00162056
		19·6397	19·4104	19·3508	− ·00055325
13	·654831	17·9314	17·7113	17·8124	− ·00186429
		19·7830	19·3769	19·3157	− ·00058317

9. *Comparison with the ephemeris. General considerations.*— We are now in a position to compare with the ephemeris, and here we come to the essential point of what I have called this experimental reduction. It was suggested by Mr. Cowell in *The Observatory* (1900 December) that there are clear advantages in using in astrographic methods a heliocentric ephemeris of the planet expressed in rectangular coordinates. He points out that the reduction of the measured positions of stars and planet to standard, by the linear transformations, corrects both stars and planet completely for the aberration of light (excepting a small term depending on the eccentricity of the Earth's orbit). For the planet this is over-correction, inasmuch as the usual method of allowing for the motion of the planet during the time the light is on its way from it to us, is to leave it uncorrected for the aberration of light and to antedate the observation by the light-time. We thus obtain the true position of the planet at the antedated time, freed from both planetary aberration and the aberration of light. If, however, we correct automatically the planet with the stars for the aberration of light, we obtain the position of the planet at the time the light left it as seen from the Earth at the time the light reached it; and this is not immediately comparable with the ephemeris in its ordinary form. This difficulty is evaded if we proceed in the following manner, for the idea of which I must acknowledge my indebtedness to Mr. Cowell's paper.

10. Let the unit of distance be the mean distance of the Earth from the Sun, and let U, V, W be the heliocentric coordinates of the planet at the epoch T (the time the light left it) referred to three rectangular axes, Su, Sv, Sw. S is the centre of the Sun; the positive directions of the axes are Su towards the vernal equinox for 1900·0; Sv in the plane of the mean ecliptic for this epoch, at right angles to Su, towards Cancer; Sw towards the north pole of the ecliptic.

Now let f, g, h be the heliocentric coordinates referred to the same axes of the centre of the Earth at epoch $T+\Delta T$ (the time when the light which left the planet at T reaches the Earth). Transform to parallel axes through the centre of the Earth, E.

$U-f$, $V-g$, $W-h$, are the coordinates of the planet at epoch T as seen from the centre of the Earth E at epoch $T+\Delta T$. (System I.)

Now transform to a new set of axes through the same origin Ex, y, z; Ez is drawn through the point on the celestial sphere corresponding to the assumed centre of the plate for 1900·0; Ey is at right angles to this in the plane of the meridian of the plate; Ex is at right angles to the others. Ex, Ey are then parallel to the axes of coordinates on the standard plate. (System II.)

If α, δ is the assumed centre of the plate, the direction cosines of the axes of System II. referred to the axes of System I. are easily found to be

$$l_1 = -\sin\alpha \qquad m_1 = -\sin\delta\cos\alpha \qquad n_1 = \cos\delta\cos\alpha$$

$$l_2 = \cos\varepsilon\cos\alpha \qquad m_2 = \sin\varepsilon\cos\delta - \cos\varepsilon\sin\delta\sin\alpha \qquad n_2 = \sin\varepsilon\sin\delta + \cos\varepsilon\cos\delta\sin\alpha$$

$$l_3 = -\sin\varepsilon\cos\alpha \qquad m_3 = \cos\varepsilon\cos\delta + \sin\varepsilon\sin\delta\sin\alpha \qquad n_3 = \cos\varepsilon\sin\delta - \sin\varepsilon\cos\delta\sin\alpha.$$

And with respect to the axes of System II. the coordinates of the planet at epoch T, as seen from E at epoch T+ΔT, are

$$x = l_1(\mathrm{U}-f)+l_2(\mathrm{V}-g)+l_3(\mathrm{W}-h) = \mathrm{L}$$
$$y = m_1(\mathrm{U}-f)+m_2(\mathrm{V}-g)+m_3(\mathrm{W}-h) = \mathrm{M}$$
$$z = n_1(\mathrm{U}-f)+n_2(\mathrm{V}-g)+n_3(\mathrm{W}-h) = \mathrm{N}$$

Again, let x_o, y_o, z_o be the coordinates of the Observatory O at epoch T+ΔT referred to the axes of System II. It is easily seen that in terms of the mean distance R of Earth from Sun

$$x_o = \frac{\rho}{\mathrm{R}}\cdot\frac{\rho'}{\rho}\cos\phi'\sin h = \pi a$$

$$y_o = \frac{\rho}{\mathrm{R}}\cdot\frac{\rho'}{\rho}(\sin\phi'\cos\delta - \cos\phi'\sin\delta\cos h) = \pi b$$

$$z_o = \frac{\rho}{\mathrm{R}}\cdot\frac{\rho'}{\rho}(\sin\delta\sin\phi' + \cos\delta\cos\phi'\cos h) = \pi c$$

where h is the hour-angle of the centre of the plate, ϕ' the reduced latitude of the Observatory, ρ' and ρ the local and equatorial radii of the Earth, π the Sun's equatorial horizontal parallax.

Transform finally to another set of axes through O, parallel to the axes of System II.

Then
$$\mathrm{X} = \mathrm{L} - a\pi$$
$$\mathrm{Y} = \mathrm{M} - b\pi$$
$$\mathrm{Z} = \mathrm{N} - c\pi$$

are the coordinates of the planet at epoch T as seen from the Observatory at epoch T+ΔT.

And the position of the planet projected upon the ideal standard plate will be

$$\xi_o = \frac{\mathrm{X}}{\mathrm{Z}} = \frac{1}{\mathrm{N}}\left\{\mathrm{L} - \left(a - \frac{c}{\mathrm{N}}\right)\pi\right\} = \nu\{\mathrm{L} - (a - c\nu)\pi\}$$

$$\eta_o = \frac{\mathrm{Y}}{\mathrm{Z}} = \frac{1}{\mathrm{N}}\left\{\mathrm{M} - \left(b - \frac{c}{\mathrm{N}}\right)\pi\right\} = \nu\{\mathrm{M} - (b - c\nu)\pi\}$$

since πc is small compared with N ; ν is written for $1/\mathrm{N}$ to avoid fractions in the printing.

Now in forming the equations of condition we must put $\pi=\pi_0+\Delta\pi$, and it will be necessary to introduce tabular corrections to the ephemeris position of the planet—it will be assumed for the present that the heliocentric ephemeris of the Earth is sufficiently good. If these corrections are ΔU, ΔV, ΔW, we have for the true ξ coordinate of the planet

$$\begin{aligned} &L+l_1\Delta U+l_2\Delta V+l_3\Delta W-a(\pi_0+\Delta\pi)\\ &N+n_1\Delta U+n_2\Delta V+n_3\Delta W-c(\pi_0+\Delta\pi)\end{aligned}$$

$$=\nu\{L-\pi_0(a-\nu c)\}+\nu(l_1\Delta U+l_2\Delta V+l_3\Delta W)-\nu(a-c\nu)\Delta\pi$$

which we will write

$$\xi=\xi_0+\Delta\xi_0-\nu(a-c\nu)\Delta\pi$$

and similarly

$$\eta=\eta_0+\Delta\eta_0-\nu(b-c\nu)\Delta\pi$$

Hence each reduced measure (ξ, η) of the planet gives us two equations of condition—

$$\nu(a-c\nu)\Delta\pi-\Delta\xi_0+\xi-\xi_0=0$$
$$\nu(b-c\nu)\Delta\pi-\Delta\eta_0+\eta-\eta_0=0$$

11. *The ephemerides.*—With very great kindness Professor Millosevich computed for me a heliocentric ephemeris of *Eros* for a part of the period during which it was under observation. My sincere acknowledgments are due to him for the readiness with which he undertook this indispensable part of the experiment.

This ephemeris, he writes, is founded upon the following elements :—

Osculation 1900 Oct. 31·5 B = epoch.

M	304° 24′ 49″·75
μ	2015″·23858
ϕ	12° 52′ 49″·93
ω	177° 39′ 8″·65
Ω	303° 30′ 42″·38
i	10° 49′ 38″·03
log a	0·1637867.

These elements represent, account being taken of perturbations by *Venus*, *Earth*, *Mars*, *Jupiter*, and *Saturn*, within one second of arc, and generally within much less than that, all the normal places available between 1898 August and 1901 April.

Heliocentric ephemeris of Eros referred to the ecliptic of 1900·0.
Professor E. Millosevich.

12h Berlin M.T. 1900.	Hel. Longitude.	Hel. Latitude.	Log. Rad. vect.
	° ′ ″	° ′ ″	
Oct. 19	33 44 48·31	+10 49 37·72	0·1373172
20	34 22 33·08	49 33·71	62860
21	35 0 28·64	49 25·06	52529
22	35 38 35·02	49 11·70	42182
23	36 16 52·26	48 53·58	31819
24	36 55 20·39	48 30·62	21442
25	37 33 59·48	48 2·76	11051
26	38 12 49·58	47 29·93	0·1300647
27	38 51 50·73	46 52·07	0·1290232
28	39 31 2·94	46 9·10	79808
29	40 10 26·27	45 20·98	69376
30	40 50 0·73	44 27·62	58938
31	41 29 46·52	43 28·97	48495
Nov. 1	42 9 43·47	42 24·95	38049
2	42 49 51·68	41 15·50	27600
3	43 30 11·20	40 0·55	17150
4	44 10 42·04	38 40·05	0·1206701
5	44 51 24·20	37 13·95	0·1196254
6	45 32 17·74	35 42·15	85811
7	46 13 22·71	34 4·56	75374
8	46 54 39·11	32 21·14	64945
9	47 36 6·93	30 31·86	54525
10	48 17 46·20	28 36·64	44117
11	48 59 36·96	26 35·41	33721
12	49 41 39·19	24 28·11	23339
13	50 23 52·89	22 14·68	12974
14	51 6 18·08	19 55·07	0·1102627
15	51 48 54·78	17 29·22	0·1092301
16	52 31 42·99	14 57·07	81998
17	53 14 42·70	12 18·56	71719
18	53 57 53·91	9 33·62	61466
19	54 41 16·64	6 42·22	51242
20	55 24 50·90	+10 3 44·28	0·1041048

The heliocentric ephemeris of the Earth is taken from the *Berliner Jahrbuch*, 1900.

Both these ephemerides are for the mean equinox 1900·0 of Leverrier's tables.

From them the ephemerides of the planet and the Earth expressed in rectangular coordinates referred to the first set of axes, through the centre of the Sun, were constructed with seven-figure logarithm tables.

12. *Formation of the equations of condition.*—The mean epochs of the exposures $T+\Delta T$ reduced to Berlin M.T. are given in Table I.

The values of ΔT, the light equation, were calculated from the values of $\log \Delta$ given by Millosevich in *A.N.* No. 3660, 1, using Gill's value of the Sun's light equation $498^s{\cdot}46$. Thus T was found.

With these values of $T-0^d{\cdot}5$ (since the ephemeris of the planet is for midnight) and of $T+\Delta T$, the values of U, V, W, f, g, h were interpolated. The third differences are small and somewhat irregular, owing largely, no doubt, to the use of only seven-figure tables.

The values of the nine direction cosines required (see paragraph 10) are :—

$l_1 -{\cdot}4891288$	$m_1 -{\cdot}7089005$	$n_1 +{\cdot}5081469$
$l_2 +{\cdot}8001604$	$m_2 -{\cdot}1328410$	$n_2 +{\cdot}5848907$
$l_3 -{\cdot}3471266$	$m_3 +{\cdot}6926858$	$n_3 +{\cdot}6322104$

The values of a, b, c were formed with the data for the Cambridge Observatory

$$\phi' = 52^\circ\ 1'\ 29''{\cdot}2$$

$$\log \rho'/\rho = \bar{1}\ {\cdot}999078$$

It should be remarked that from this point no more logarithms were used. The whole of the rest of the calculations, as well as all the foregoing interpolations, were done on an arithmometer (the Thomas de Colmar), which calculates quantities of the form

$$l_1(U-f)+l_2(V-g)+l_3(W-h)$$

with great ease. It seems to me that this possibility of using an arithmometer almost throughout is a strong point of the method.

Table II. contains the quantities required in the formation of the equations of condition.

TABLE

Quantities required in the formation

No.		T−0ᵈ·5	U	V	W	*f*	*g*	*h*
	Series A.							
1	Nov.	9·050204	+·8641836	+·9476201	+·2378653	+·6731748	+·7258077	+ 5 × 10⁻⁷
2		·103210	34709	80585	7979	24912	64246	5
3		·147103	28805	84212	7421	19248	69348	5
4		·186380	23520	87456	6920	14175	73911	6
5		·227238	·8618020	·9490828	·2376399	·6708895	·7278654	6
6		·774938	·8544107	·9535828	·2369364	·6637790	·7341874	9
7		·815713	38591	39163	8837	32472	46554	9
8		·854698	33315	42349	8332	27384	51025	9
9		9·961960	18790	51106	6940	13370	63309	9
10		10·013438	11814	55303	6271	06636	69196	10
11		·063477	·8505030	59380	5620	·6600085	74912	10
12		·103702	·8499575	62655	5096	·6594815	79503	10
13		10·147999	+·8493565	+·9566259	+·2364518	+·6589008	+·7384555	+10
	Series B.							
1		9·054750	+·8641220	+·9476581	+·2378595	+·6731157	+·7258612	+ 5 × 10⁻⁷
2		·107279	34162	80921	7927	24387	64719	5
3		·151200	28254	84551	7368	18719	69825	5
4		·191109	22883	87846	6860	13564	74460	6
5		·231422	·8617456	·9491173	·2376346	·6708354	·7279139	6
6		·779209	·8543529	·9536177	·2369309	·6637233	·7342364	9
7		·820241	37978	39533	8778	31881	47073	9
8		·859344	32686	42729	8272	26777	51558	9
9		9·966371	18192	51466	6883	12793	63814	9
10		10·017362	11282	55623	6220	·6606122	69644	10
11		·067775	·8504447	59730	5564	·6599522	75403	10
12		·108001	·8498992	63005	5040	94252	79993	10
13		10·152671	+ 8492931	+·9566639	+·2364457	+·6588395	+·7385087	+10

II.

of the equations of condition.

L	M	N	$\nu(a-c\nu)$	$\nu(b-c\nu)$	ξ_0	η_0
+·00148839	−·00010645	+·37717714	+0·6742	+0·0153	+·00391740	−·00028288
138320	10879	701534	1·1249	0·2662	362088	29990
129628	11084	688159	1·4031	0·5539	339970	31770
121853	11306	676194	1·5613	0·8552	316769	33652
113768	11534	663763	+1·6248	1·1916	295138	35702
+·00006144	16176	498432	−1·5695	0·8430	023073	46730
−·00001820	16636	486228	1·3991	0·5318	+·00001107	46645
009430	17094	474564	1·1500	+0·2762	−·00020263	46792
030320	18428	442538	−0·1661	−0·1005	080269	48789
040333	19109	427188	+0·3633	−0·0748	109312	50737
050048	19789	412302	0·8427	+0·0802	137365	53236
057855	20359	400352	1·1700	0·2879	159677	55662
−·00056442	−·00021000	+·37387197	+1·4439	+0·5851	−·00183866	−·00058662
+·00147923	−·00010663	+·37716314	+0·7200	+0·0333	+·00389131	−·00028414
137511	10901	700292	1·1548	0·2901	359827	30151
128815	11111	686905	1·4236	0·5836	335736	31969
120917	11326	674752	1·5742	0·8932	314242	33869
112944	11552	662492	+1·6247	1·2498	292960	35998
·00005310	16220	497153	−1·5564	0·8087	+·00020794	46703
−·00002700	16690	484871	1·3743	0·4996	−·00001346	46654
010338	17150	473178	1·1156	+0·2493	022834	46828
031180	18482	441223	−0·1209	−0·1037	082762	48920
041092	19164	426025	+0·4026	−0·0671	111511	50919
050884	19848	411021	0·8804	+0·0989	139765	53475
058683	20419	399077	1·2008	0·3139	162027	55936
·00057343	−·00021072	+·37385815	+1·4664	+0·6201	−·00186379	−·00059007

Equations of condition.

	Series A.			π_1	π_2	v
ξ 1	$+0.67\Delta\pi - 1\Delta\xi_0$			-28×10^{-7}	$-2\times10^{-7}=0$	$+4\times10^{-7}$
2	+1·12	−1		−30	− 6	− 1
3	+1·40	−1		−39	−16	− 9
4	+1·56	−1		−22	0	+ 5
5	+1·62	−1		− 9	+12	+17
6	−1·57	−1		− 3	+ 3	+ 9
7	−1·40	−1		−15	−10	− 4
8	−1·15	−1		−10	− 6	0
9	−0·17	−1		−11	−10	− 4
10	+0·36	−1		−14	−14	− 8
11	+0·84	−1		− 7	− 9	− 3
12	+1·17	−1		− 2	− 5	0
13	+1·44	−1		− 7	−11	− 6
η 1	+0·02		$-1\Delta\eta_0$	+71	+67	− 1
2	+0·27		−1	+71	+67	− 1
3	+0·55		−1	+79	+76	+ 8
4	+0·86		−1	+83	+80	+12
5	+1·19		−1	+59	+56	−12
6	+0·84		−1	+68	+67	− 1
7	+0·53		−1	+73	+72	+ 4
8	+0·28		−1	+61	+60	− 8
9	−0·10		−1	+67	+67	− 1
10	−0·07		−1	+66	+66	− 2
11	+0·08		−1	+69	+69	+ 1
12	+0·29		−1	+69	+69	+ 1
13	+0·59		−1	+70	+71	+ 3

	Series B.		π_1	π_2	v
ξ 1	$+0.72\Delta\pi - 1\Delta\xi_0$		-25×10^{-7}	$-4\times10^{-7}=0$	$+2\times10^{-7}$
2	+1·15	−1	−33	−13	− 9
3	+1·42	−1	−26	− 7	− 3
4	+1·57	−1	−25	− 7	− 4
5	+1·62	−1	− 4	+13	+16
6	−1·56	−1	−17	−12	+ 2
7	−1·37	−1	−23	−19	− 6
8	−1·12	−1	− 6	− 3	+ 9
9	−0·12	−1	− 7	− 6	+ 3
10	+0·40	−1	− 4	− 4	+ 3

	Series B.			n_1	n_2	v
11	$+0\cdot88\Delta\pi$	$-1\Delta\xi_0$		-10×10^{-7}	$-12\times10^{-7}=0$	-7×10^{-7}
12	$+1\cdot20$	-1		-3	-5	-1
13	$+1\cdot47$	-1		-5	-8	-5
η 1	$+0\cdot03$		$-1\Delta\eta_0$	$+68$	$+60$	-5
2	$+0\cdot29$		-1	$+72$	$+65$	-1
3	$+0\cdot58$		-1	$+80$	$+71$	$+4$
4	$+0\cdot89$		-1	$+74$	$+66$	-2
5	$+1\cdot25$		-1	$+88$	$+82$	$+13$
6	$+0\cdot81$		-1	$+67$	$+65$	-3
7	$+0\cdot50$		-1	$+64$	$+63$	-4
8	$+0\cdot25$		-1	$+61$	$+60$	-6
9	$-0\cdot10$		-1	$+62$	$+62$	-3
10	$-0\cdot07$		-1	$+70$	$+70$	$+5$
11	$+0\cdot10$		-1	$+66$	$+67$	$+2$
12	$+0\cdot31$		-1	$+61$	$+62$	-4
13	$+0\cdot62$		-1	$+69$	$+70$	$+3$

The numerical terms which arise from the combination of the quantities of Table II. are found in the column n_1. They are expressed in terms of the length of the radius of projection on to the plate; that is to say, they are independent of the focal length of the particular telescope employed, so that the equations could be combined immediately with the work of other telescopes reduced in the same way.

13. *Empirical correction of the ephemeris.*—A glance at the terms in column n_1 of the ξ equations shows that the equations cannot be satisfied as they stand. We must introduce a correction to the ephemeris varying with the time.

An approximate value of this correction was found as follows:

Taking groups of equations of condition which have similar parallax factors on the two nights, and writing them in the form

$$a\Delta\pi+\Delta\xi_0+\Delta'\xi_0 t+n=0$$

we have from among the ξ equations of Series A:

1	$+0\cdot67$	$\Delta\pi+\Delta\xi_0$	$+0\cdot05$	$\Delta'\xi_0$	$-28=0$
2	$+1\cdot12$		$+0\cdot10$		-30
3	$+1\cdot40$		$+0\cdot15$		-39
11	$+0\cdot84$		$+1\cdot06$		-7
12	$+1\cdot17$		$+1\cdot10$		-2
13	$+1\cdot44$		$+1\cdot15$		-7

and subtracting the mean of the first three from the mean of the second

$$0{\cdot}09\,\Delta\pi + 1{\cdot}00\,\Delta'\xi_0 + 27 = 0.$$

The effect of $\Delta\pi$ is inappreciable. Proceeding in the same way with the other groups we find that the corrections to be added to the numerical terms to allow for an error in the ephemeris varying with the time are

	Series A	Series B
$\Delta'\xi_0 =$	$-27t$	$-22t$
$\Delta'\eta_0 =$	$+\ 4t$	$+\ 8t$

Reckoning t from Berlin midnight on November 10, the corrected values of the numerical terms are found in the column n_2 of the equations of condition.

This does not, however, necessarily represent a real correction to the assumed motion of the planet. The greater part may be due to the accumulation of error in adding two separate ephemerides each computed with seven-figure logarithm tables. The necessity for it should disappear with more accurate ephemerides. It has been used here as a temporary expedient, and it is practicable only when we have observations on two consecutive nights at the same hour-angles, which was not a common case last winter.

14. *Solution of the equations of condition.*—In this preliminary solution equal weight has been given to each equation.

The normal equations from the twenty-six equations of condition of Series A are :

$$\begin{aligned}
+22{\cdot}83\,\Delta\pi - 5{\cdot}89\,\Delta\xi_0 - 5{\cdot}33\,\Delta\eta_0 + 336{\cdot}59 &= 0\\
-\ 5{\cdot}89\,\Delta\pi + 13{\cdot}00\,\Delta\xi_0 \quad 0{\cdot}00\,\Delta\eta_0 + 74{\cdot}00 &= 0\\
-\ 5{\cdot}33\,\Delta\pi \quad 0{\cdot}00\,\Delta\xi_0 + 13{\cdot}00\,\Delta\eta_0 - 887{\cdot}00 &= 0
\end{aligned}$$

And their solution gives

P.E. of one equation $\pm 4{\cdot}63$ or		$\pm 0''{\cdot}096$	Wt.
$\Delta\pi = -\ 0{\cdot}36 \pm 1{\cdot}09$	„	$-0''{\cdot}007 \pm 0''{\cdot}023$	17·97
$\Delta\xi_0 = -\ 5{\cdot}85 \pm 1{\cdot}38$	„	$-\ 0{\cdot}12 \pm 0{\cdot}028$	11·32
$\Delta\eta_0 = +68{\cdot}08 \pm 1{\cdot}36$	„	$+\ 1{\cdot}40 \pm 0{\cdot}028$	11·59

Similarly for Series B_4':

$$\begin{aligned}
+23{\cdot}31\,\Delta\pi - 6{\cdot}26\,\Delta\xi_0 - 5{\cdot}46\,\Delta\eta_0 + 381{\cdot}65 &= 0\\
-\ 6{\cdot}26\,\Delta\pi + 13{\cdot}00\,\Delta\xi_0 \quad 0{\cdot}00\,\Delta\eta_0 + 87{\cdot}00 &= 0\\
-\ 5{\cdot}46\,\Delta\pi \quad 0{\cdot}00\,\Delta\xi_0 + 13{\cdot}00\,\Delta\eta_0 - 863{\cdot}00 &= 0
\end{aligned}$$

P.E. of one equation $\pm 4{\cdot}26$ or		$\pm 0''{\cdot}088$	Wt.
$\Delta\pi = -\ 3{\cdot}40 \pm 1{\cdot}01$	„	$-0''{\cdot}070 \pm\ 0{\cdot}021$	18·00
$\Delta\xi_0 = -\ 8{\cdot}33 \pm 1{\cdot}28$	„	$-\ 0{\cdot}17 \pm\ 0{\cdot}026$	11·13
$\Delta\eta_0 = +64{\cdot}85 \pm 1{\cdot}25$	„	$+\ 1{\cdot}34 \pm\ 0{\cdot}026$	11·53

The residuals which arise from substituting these values of the unknowns in the equations of condition are given in the last column of the table. It will be noticed that the residuals in the four equations No. 5, which represent the last set of exposures on November 9, are unduly large. I have remeasured the images of the planet and examined the reductions, and can find no error. The zenith distance was about 50° and the images are bad; indeed throughout the whole of these two nights the seeing was not at all good; they were the first frosty nights of the winter.

It does not seem necessary to give the value of π_0 which has been assumed in these reductions, as it is inadvisable to multiply results which are in no sense definitive, even for the small number of observations here discussed.

15. The difference 0″·06 between the results of Series A (stars fixed) and Series B (planet fixed) looks somewhat large, though it is well within the possible difference of two results each with a P.E. $\pm$0″·02. For the present I should prefer to look upon it as bad luck, and should deprecate the drawing of any conclusion confirmatory of the fears that have been expressed that systematic error may arise from the motion of the planet. If such error were independent of the magnitude, and a function only of the motion of the planet and the time of exposure—that is to say, of the length of the trail—each series would give a value of the parallax free from systematic error, since the time of exposure and the motion of the planet were sensibly constant for the two nights; and both would give similarly erroneous values of the tabular corrections. If the error were a function of the magnitude, which varies effectively with the zenith distance, it should nevertheless be eliminated by the method here employed of reducing by means of comparison stars very nearly equal to the planet in magnitude. Moreover some evidence has been given that, even for stars on the limit of photographic action for the particular exposure, no certain trace of the effects of trail is discoverable. I prefer then to draw no further conclusion from the discrepancy than that it will be wise to adhere to my resolution to keep the two series separate right through the work.

16. *Tabular errors of the planet.*—It is a not inconsiderable advantage of this method that we can easily derive from the values found for $\Delta\xi_0$, $\Delta\eta_0$, the corrections to the tabular heliocentric longitude and latitude of the planet, if we assume that the ephemeris of the Earth is accurate.

From the relations between U, V, W and λ, β, R, the heliocentric longitude, latitude, and radius vector, we have

$$\Delta U = \cos\beta\cos\lambda\,.\,\Delta R - R\cos\beta\sin\lambda\,.\,\Delta\lambda - R\cos\lambda\sin\beta\,.\,\Delta\beta$$

$$\Delta V = \cos\beta\sin\lambda\,.\,\Delta R + R\cos\beta\cos\lambda\,.\,\Delta\lambda - R\sin\lambda\sin\beta\,.\,\Delta\beta$$

$$\Delta W = \sin\beta\,.\,\Delta R + R\cos\beta\,.\,\Delta\beta$$

And we had

$$\nu\,\Delta\xi_0 = l_1\,\Delta U + l_2\,\Delta V + l_3\,\Delta W$$
$$\nu\,\Delta\eta_0 = m_1\,\Delta U + m_2\,\Delta V + m_3\,\Delta W$$

Putting in the values of β, λ, R, l_1 ... &c. we obtain two equations for $\Delta\lambda$ and $\Delta\beta$ in terms of ΔR:

$$1{\cdot}148\,\Delta\lambda - 0{\cdot}509\,\Delta\beta = -\,1{\cdot}89 - 0{\cdot}204\,\Delta R$$
$$+0{\cdot}564\,\Delta\lambda + 1{\cdot}021\,\Delta\beta = +17{\cdot}73 + 0{\cdot}435\,\Delta R$$

whence

$$\Delta\lambda = +\,4{\cdot}9 + 0{\cdot}009\,\Delta R$$
$$\Delta\beta = +14{\cdot}7 + 0{\cdot}421\,\Delta R.$$

ΔR must be derived from an extended comparison with observation of the theory of the planet's motion. Putting it zero for the present, we have $\Delta\lambda = +0''{\cdot}10$ $\Delta\beta = +0''{\cdot}30$.

There is, therefore, no need to introduce a geocentric ephemeris of the planet at any point of the work. I have used the values of log Δ from Millosevich's ephemeris to get the light equation, because they were ready to hand. But the geocentric distances of the planet are easily found from

$$\Delta^2 = (U-f)^2 + (V-g)^2 + (W-h)^2.$$

17. *Conclusions.*—To sum up, I should suggest that the following conclusions may be drawn from the results of this experimental reduction of a small series of *Eros* plates.

(1) The smallness of the probable error of an equation of condition, even with a comparatively rough ephemeris, is a good omen for the ultimate success of the enterprise.

(2) It is an absolute necessity to have ephemerides computed with eight-figure logarithms. This is indeed a truism, for since Sir David Gill found that it was necessary for his heliometer determination of the solar parallax, we should be wasting time now if our results were not good enough to demand it.

(3) There is only one complete set of eight-figure tables in existence—viz. those published by the French *Service Géographique de l'Armée*, which are based on the centesimal division of the quadrant. *We must therefore work in the centesimal system.* Professor Bauschinger kindly informs me that the ephemeris of Victoria for Sir David Gill was computed in the K. Rechen Institut, Berlin, in grades, and afterwards converted into degrees, "was einige lästige Mehrarbeit verursacht." There does not seem to be any good reason why we should give ourselves this extra labour.

(4) I hope that the present reduction has sufficiently shown the advantages which arise from working with the separate heliocentric ephemerides of the Earth and *Eros*, instead of with the usual geocentric ephemeris of the planet. Briefly, they are

(*a*) the ephemeris of the Earth can be computed once for all; the ephemeris of the planet can with comparatively small labour be improved from time to time as we proceed, and the corrections can be carried into our equations of condition with the minimum of trouble. (*b*) The interpolations from the heliocentric ephemerides are not so troublesome as from a geocentric; the quantities vary more regularly. (*c*) The greater part of the calculation is done on a machine instead of with logarithms, which saves a deal of writing. (*d*) The form of the work is comparatively simple, and you see clearly what you are doing all through.

(5) Since the sub-committee of the *Comité International Permanent* is publishing the revised places of the standard stars referred to Newcomb's Fundamental Catalogue, it will be necessary to refer the elements of the orbit of *Eros* to Newcomb's system—at present they are based on Leverrier's—and to compute the ephemeris of the Earth from Newcomb's tables of the Sun, with Gill's value for the mass of the Moon.

(6) Finally, the great advantage is that photographic results reduced on these lines by different observatories would be most readily available for a general combination. And the micrometric results could be easily included, for they are essentially measures in rectangular coordinates, and they might be reduced in exactly the same way.

Cambridge Observatory:
1901 *November* 6.

The Determination of Selenographic Positions and the Measurement of Lunar Photographs.

[Second Paper.]

Determination of a first group of Standard Points by Measures made at the Telescope and on Photographs. By S. A. Saunder, M.A.

§ 1. *Recapitulation of First Paper.*

In a previous paper (*Monthly Notices*, vol. lx. p. 174) I called attention to the unsatisfactory state of our knowledge of the exact positions of the lunar formations, and to the increase in accuracy which might be obtained by measuring from the well-determined point *Mösting A*; formulæ were developed for reducing the measures, and a few results were given.

It was also shown that by the measurement of such photographs as those now being taken at the Paris Observatory a great increase might be made in the number of points whose positions could be accurately determined without necessitating

an inordinate amount of computation. Formulæ were developed for reducing the measures on the assumption that the positions of a number of points were known with sufficient accuracy, but it was found that the accepted positions of "points of the first order" were not accurate enough to give the best results obtainable from the photographs, and a second method was developed depending partly on measures of the limb, partly on a combination of measures of the same points on two different photographs, somewhat analogous to the optical combination of two pictures by the stereoscope. Some tentative results were given, and in conclusion I expressed my intention of attacking other pairs of plates in the same way.

Further work on the same pair however showed that the constants obtained ought to be capable of improvement; there were signs of a progressive error, which I now know to have been due to an error of scale on one of the plates. This error was not of sufficient magnitude to vitiate the general conclusions drawn in the paper. I soon became convinced that no really satisfactory solution was likely to be obtained so long as any part of the work depended on measures of the limb. I then tried to determine the plate constants by an extension of what I have called the stereoscopic method, and when this failed, as will be described below, I had recourse to the telescope, and proceeded to determine the positions of a number of points surrounding *Mösting A* at distances not much exceeding 500″, this limit being imposed by the construction of my micrometer.

§ 2. *Telescopic Measures on the Moon.*

These measures were all made and reduced as described in § 3 to § 6 of the previous paper, the only change in detail being that, with the notation of § 4, when ξ', η', ζ' have been once measured the equation $z'=a_3\xi'+b_3\eta'+c_3\zeta'$ has been used to compute the value of $1-z'\sin s'$, the value of z' thus obtained being always sufficiently accurate for the purpose. x', y' have then been determined from the equations at the bottom of p. 177.

$$x'=z\frac{1-z'\sin s'}{1-z\sin s'}-Q(1-z'\sin s')\sin(P-C)$$

$$y'=y\frac{1-z'\sin s'}{1-z\sin s'}+Q(1-z'\sin s')\cos(P-C)$$

This saves the steps required to compute the quantities denoted by x_1', y_1', z_1'.

When the work was nearly completed I found that Dr. Franz of Breslau had already applied the method of measurement from *Mösting A* to determine the positions of eight other points, his results having been published in an Appendix to vol. xxxviii. of the Königsberg Observations a short time before my paper was read (see also *Monthly Notices*, vol. lxi. p. 265).

These measures have been of great use to me as will be explained below. The places expressed in terms of rectangular coordinates are :

Proclus	...	$\xi = +\cdot70222 \pm \cdot00012$	$\eta = +\cdot27698 \pm \cdot00020$	
Macrobius *a*	...	$+\cdot61034 \pm$	12	$+\cdot33455 \pm$ 20
Sharp A	...	$-\cdot45663 \pm$	23	$+\cdot73763 \pm$ 15
Aristarchus	...	$-\cdot67551 \pm$	17	$+\cdot40201 \pm$ 21
Gassendi *z*	...	$-\cdot65246 \pm$	12	$-\cdot28330 \pm$ 15
Byrgius A	...	$-\cdot81612 \pm$	17	$-\cdot41561 \pm$ 20
Nicolai A	...	$+\cdot29598 \pm$	11	$-\cdot67494 \pm$ 14
Fabricius K	...	$+\cdot46642 \pm$	16	$-\cdot72018 \pm$ 17

The measures were all made with the Königsberg heliometer, and the observations extend over a period of six years. *Byrgius A* was measured on eight different nights ; the others depend each on from eleven to thirteen separate determinations.

An account of the measures of *Ptolemæus A* and *Triesnecker B*, kindly made for me by Professor Barnard, has already appeared (*Monthly Notices*, vol. lx. p. 540), together with the particulars of my own measures of these points (see also *Astronomical Journal*, vol. xxii. p. 33).

Four measures of *Dollond* are given in *Monthly Notices*, vol. lx. p. 182.

These, with *Mösting A* and those given below, complete the list of the positions used in the reduction of the photographic plates.

A complete set of measures consists, as described in § 6 of my previous paper, of six settings for position-angle, five double distances, and six more settings for position-angle. Occasionally a set has been interrupted by clouds or by failure of definition. If less than half the whole set had been made, no account has been taken of them ; if more than half, they have been reduced and allowed weight $\frac{1}{2}$ in the final means. No place depends on less than four complete sets or their equivalent.

The probable error of a coordinate derived from one complete set, as determined from the whole of the residuals, is ·00022, and hence the probable error of the mean of four such measures is ·00011, the geocentric value of which is 0″·10.

Results of micrometric measures made on the Moon with a 7-inch O.G.

Hesiodus B.

			Residual.		Residual.	
1899 Dec.	14	$\xi = -\cdot2670$	$+\cdot0001 \times \frac{1}{2}$	$\eta = -\cdot4553$	$+\cdot0002 \times \frac{1}{2}$	Wt. $\frac{1}{2}$
	15	$-\cdot2673$	2	$-\cdot4554$	+ 1	
1900 Feb.	11	$-\cdot2673$	2	$-\cdot4558$	− 3	
Nov.	9	$-\cdot2664$	+ 7	$-\cdot4554$	+ 1	
1901 Apr.	1	$-\cdot2676$	− 5	$-\cdot4555$	0	
		$-\cdot2671$		$-\cdot4555$		

Nicollet.

			Residual.		Residual.
1900 Aug.	17	$\xi = -\cdot1995$	$+\cdot0003$	$\eta = -\cdot3729$	$+\cdot0001$
Oct.	13	$-\cdot1999$	$-\ 1$	$-\cdot3732$	$-\ 2$
1901 Jan.	29	$-\cdot1997$	$+\ 1$	$-\cdot3732$	$-\ 2$
Feb.	1	$-\cdot2001$	$-\ 3$	$-\cdot3726$	$+\ 4$
		$-\cdot1998$		$-\cdot3730$	

Thebit A.

1900 Apr.	10	$\xi = -\cdot0785$	$+\cdot0007$	$\eta = -\cdot3672$	$+\cdot0002$
	13	$-\cdot0795$	$-\ 3$	$-\cdot3675$	$-\ 1$
May	7	$-\cdot0792$	0	$-\cdot3671$	$+\ 3$
Nov.	10	$-\cdot0796$	$-\ 4$	$-\cdot3676$	$-\ 2$
		$-\cdot0792$		$-\cdot3674$	

Abenezra b.

1900 Sept.	12	$\xi = +\cdot1634$	$-\cdot0001$	$\eta = -\cdot3555$	$-\cdot0003$
Oct.	10	$+\cdot1635$	0	$-\cdot3546$	$+\ 6$
1901 Jan.	31	$+\cdot1633$	$-\ 2$	$-\cdot3557$	$-\ 5$
Feb.	28	$+\cdot1636$	$+\ 1$	$-\cdot3551$	$+\ 1$
		$+\cdot1635$		$-\cdot3552$	

Airy A.

1900 Sept.	12	$\xi = +\cdot1276$	$\cdot0000$	$\eta = -\cdot2927$	$+\cdot0002$
Oct.	10	$+\cdot1275$	$-\ 1$	$-\cdot2929$	0
1901 Jan.	29	$+\cdot1281$	$+\ 5$	$-\cdot2927$	$+\ 2$
Mar.	3	$+\cdot1274$	$-\ 2$	$-\cdot2931$	$-\ 2$
		$+\cdot1276$		$-\cdot2929$	

Lubiniezky B.

1900 Apr.	13	$\xi = -\cdot3863$	$\cdot0000$	$\eta = -\cdot2512$	$+\cdot0003$
Aug.	17	$-\cdot3865$	$-\ 2$	$-\cdot2515$	0
Oct.	14	$-\cdot3865$	$-\ 2$	$-\cdot2514$	$+\ 1$
1901 Jan.	2	$-\cdot3861$	$+\ 2$	$-\cdot2517$	$-\ 2$
		$-\cdot3863$		$-\cdot2515$	

Hipparchus C.

1900 Apr.	13	$\xi = +\cdot1420$	$-\cdot0003$	$\eta = -\cdot1288$	$-\cdot0003$
May	7	$+\cdot1424$	$+\ 1$	$-\cdot1290$	$-\ 5$
Aug.	13	$+\cdot1423$	0	$-\cdot1283$	$+\ 2$
1901 Jan.	2	$+\cdot1423$	0	$-\cdot1281$	$+\ 4$
		$+\cdot1423$		$-\cdot1285$	

Euclides.

			Residual.		Residual.
1899	Dec. 13	$\xi = -\cdot4886$	·0000	$\eta = -\cdot1279$	+·0004
	15	−·4887	1	−·1283	0
1901	Feb. 11	−·4883	+3	−·1283	0
	Nov. 10	−·4888	−2	−·1286	−3
		−·4886		−·1283	

Hipparchus G.

1900	Nov. 9	$\xi = +\cdot1289$	+·0002	$\eta = -\cdot0871$	+·0004
	10	+·1290	+3	−·0871	+4
1901	Jan. 4	+·1285	−2	−·0880	−5
	Feb. 1	+·1284	−3	−·0878	−3
		+·1287		−·0875	

Gambart A.

1900	Mar. 12	$\xi = -\cdot3205$	+·0005	$\eta = +\cdot0173$	+·0003
	13	−·3211	−1	+·0170	+0
	Apr. 10	−·3210	0	+·0171	+1
	Nov. 9	−·3214	−4	+·0167	−3
		−·3210		+·0170	

Cayley.

1900	Aug. 12	$\xi = +\cdot2599$	−·0004	$\eta = +\cdot0691$	+·0001
	13	+·2603	0	+·0691	+1
1901	Jan. 30	+·2604	+1	+·0689	−1
	Feb. 28	+·2606	+3	+·0690	0
		+·2603		+·0690	

Hortensius.

1900	Aug. 17	$\xi = -\cdot4662$	·0000	$\eta = +\cdot1127$	−·0001
	Oct. 14	−·4662	0	+·1128	0
1901	Jan. 2	−·4657	+5	+·1134	+6
	30	−·4664	−2	+·1122	−6
	31	−·4666	−4 × ½	+·1127	−1 × ½ Wt. ½
		−·4662		+·1128	

Sosigenes a.

1900	Nov. 10	$\xi = +\cdot3141$	−·0004 × ½	$\eta = +\cdot1357$	+·0008 × ½ Wt. ½
	Dec. 29	+·3149	+4 × ½	+·1353	+4 × ½ Wt. ½
1901	Jan. 29	+·3147	+2	+·1348	−1
	Feb. 28	+·3145	0	+·1346	−3
	Mar. 3	+·3143	−2	+·1346	−3
		+·3145		+·1349	

Bode B.

			Residual.		Residual.
1900	Sept. 12	$\xi = -\cdot0526$	$+\cdot0003$	$\eta = +\cdot1522$	$-\cdot0003$
	Oct. 13	$-\cdot0528$	$+\quad1$	$+\cdot1524$	$-\quad1$
1901	Jan. 31	$-\cdot0530$	$-\quad1$	$+\cdot1525$	$\quad0$
	Feb. 1	$-\cdot0534$	$-\quad5$	$+\cdot1530$	$+\quad5$
		$-\cdot0529$		$+\cdot1525$	

Bode A.

1899	Dec. 15	$\xi = -\cdot0203$	$-\cdot0004$	$\eta = +\cdot1570$	$+\cdot0001$
1900	Mar. 9	$-\cdot0194$	$+\quad5$	$+\cdot1569$	$\quad0$
	12	$-\cdot0198$	$+\quad1$	$+\cdot1568$	$-\quad1$
	13	$-\cdot0200$	$-\quad1$	$+\cdot1569$	$\quad0$
		$-\cdot0199$		$+\cdot1569$	

Bessel.

1900	Aug. 12	$\xi = +\cdot2853$	$-\cdot0003$	$\eta = +\cdot3707$	$+\cdot0003$
	13	$+\cdot2852$	$-\quad4$	$+\cdot3709$	$+\quad5$
1901	Jan. 2	$+\cdot2855$	$-\quad1$	$+\cdot3697$	$-\quad7$
	4	$+\cdot2864$	$+\quad8$	$+\cdot3700$	$-\quad4$
	Apr. 1	$+\cdot2856$	$\quad0$	$+\cdot3706$	$+\quad2$
		$+\cdot2856$		$+\cdot3704$	

§ 3. *Attempt to determine Absolute Places from a comparison of two Photographs only.*

The unsuccessful attempt to improve the constants for the plates denoted by the numbers II., III. in my previous paper, to which I referred in my first paragraph, was made as follows :—

The standard coordinates of a point ξ, η are connected with the plate coordinates x, y and the third coordinate $z=\sqrt{1-x^2-y^2}$, as shown in *Monthly Notices*, vol. lx. p. 187, by the equations

$$\xi = Ax + By + Cz$$
$$\eta = Dx + Ey + Fz$$

where A, B . . . are given as functions of the librations and of θ, the orientation of the réseau on the plate. All the coordinates are expressed as fractions of the Moon's radius, and referred to the centre of the Moon as origin.

If a small error $\delta\theta$ has been made in the assumed orientation it was shown (*Monthly Notices*, vol. lx. p. 189) that the corresponding errors in ξ, η are $(Bx-Ay)\,\delta\theta$ and $(Dx-Ey)\,\delta\theta$ respectively.

But errors may also have been made in α' β', the assumed réseau coordinates of the centre of the Moon's disc, and in r', the assumed value of the radius, also in réseau units. Let $\xi\alpha'$, $\xi\beta'$, $\xi r'$ be the amounts of these errors in réseau units; $\xi\alpha$, $\delta\beta$, δr the same quantities expressed in terms of the Moon's radius.

Let x', y' be the réseau coordinates of the point as actually read, *i.e.* referred to one corner of the réseau as origin.

Then
$$x=\frac{x'-\alpha'}{r'}, \quad y=\frac{y'-\beta'}{r'}$$

$$\therefore \xi x=\frac{-r'\delta\alpha'-(x'-\alpha')\xi r'}{r'^2}$$

$$=-\frac{\delta\alpha'}{r'}-\frac{x'-\alpha'}{r'}\frac{\delta r'}{r'}$$

$$=-\xi\alpha-x\xi r$$

Similarly
$$\xi y=-\delta\beta-y\delta r$$

And since
$$z=\sqrt{1-x^2-y^2}$$

$$\therefore \delta z=-\frac{x\delta x+y\delta y}{z}$$

$$=\frac{x}{z}\delta\alpha+\frac{y}{z}\delta\beta+\frac{1-z^2}{z}\delta r$$

And hence

$$\delta\xi=A\delta x+B\delta y+C\xi z+(Bx-Ay)\delta\theta$$

$$=\left(C\frac{x}{z}-A\right)\delta\alpha+\left(C\frac{y}{z}-B\right)\delta\beta+\frac{C}{z}\delta r-(Ax+By+Cz)\delta r$$
$$+(Bx-Ay)\delta\theta$$

$$=\left(C\frac{x}{z}-A\right)\delta\alpha+\left(C\frac{y}{z}-B\right)\delta\beta+\left(\frac{C}{z}-\xi\right)\delta r+(Bx-Ay)\delta\theta$$

Similarly

$$\delta\eta=\left(F\frac{x}{z}-D\right)\delta\alpha+\left(F\frac{y}{z}-E\right)\delta\beta+\left(\frac{F}{z}-\eta\right)\delta r+(Dx-Ey)\delta\theta$$

To determine these corrections thirty-seven points were measured on each of the two plates, the measures were reduced with the approximate values of α', β', r', and θ already obtained, and then thirty-seven equations were made of the type

$$\xi_2+\delta\xi_2=\xi_3+\delta\xi_3$$

and thirty-seven of the type

$$\eta_2+\delta\eta_2=\eta_3+\delta\eta_3$$

where the suffixes indicate the plate on which the measures were made.

These gave seventy-four equations for determining the eight quantities, δa_2, $\delta\beta_2$, δr_2, $\delta\vartheta_2$, δa_3, $\delta\beta_3$, δr_3, $\delta\theta_3$.

When these were combined by least squares, and the normal equations solved by Gauss' method of elimination, it was found that so long as one of each of the quantities δa, $\delta\beta$, $\delta\theta$, δr remained in the equations the coefficients of the first term in each equation ranged between 7·8 and 36·9, but that so soon as all the quantities belonging to one plate had been eliminated the first coefficient of the next equation fell to between ·01 and ·04, according to the order of elimination, showing that the values which would be given by the solution would be of very low weight, whilst on pushing to a numerical result a position of the centre was obtained which was known to be in error by something like three seconds of arc.

The reason for this may be seen by considering any pair of the normal equations; if, for example, we take those in δa_2, δa_3, these, as written in the usual form, were

$$37{\cdot}0643\delta a_2 - 36{\cdot}1251\delta a_3 + {\cdot}1831\delta\beta_2 + 9{\cdot}3175\delta\beta_3 + 1{\cdot}5436\delta\vartheta_2 + 1{\cdot}8799\delta\theta_3 - 2{\cdot}7882\delta r_2 - 5{\cdot}1871\delta r_3 + {\cdot}0040061 = 0$$

$$-36{\cdot}1251\delta a_2 + 37{\cdot}7490\delta a_3 - 9{\cdot}8515\delta\beta_2 + {\cdot}2599\delta\beta_3 - 1{\cdot}1806\delta\theta_2 - {\cdot}5903\delta\theta_3 + 2{\cdot}9563\delta r_2 + 6{\cdot}0044\delta r_3 - {\cdot}0037328 = 0$$

If we put $\delta a_2 + \delta a_3 = 2A$, $\delta a_2 - \delta a_3 = 2a$, the first two terms become

$$\cdot 9392A + 73{\cdot}1894a \text{ in the first equation,}$$
$$1{\cdot}6239A - 73{\cdot}8741a \text{ in the second equation,}$$

whence we see that while the differences are well determined the sums have very small coefficients; and the same holds true for all the pairs of normal equations.

The interpretation is that the unavoidable errors of observation were such that the difference between the librations was not sufficient to give more than a rough approximation to the absolute values of the required constants.

§ 4. *Formation of Equations by Combination of the Telescope and Photographic Measures.*

The work, however, was not entirely lost, for by stopping the elimination when only half effected it was possible (as explained in *Chauvenet*, vol. ii., Appendix, § 52) to obtain four good equations:

$$\delta a_2 = P\delta a_3 + Q\ \delta\beta_3 + R\ \delta r_3 + S\ \delta\theta_3 + T \pm {\cdot}000031$$
$$\delta\beta_2 = P'\delta a_3 + Q'\ \delta\beta_3 + R'\ \delta r_3 + S'\ \delta\theta_3 + T' \pm {\cdot}000031$$
$$\delta r_2 = P''\delta a_3 + Q''\ \delta\beta_3 + R''\ \delta r_3 + S''\ \delta\theta_3 + T'' \pm {\cdot}000067$$
$$\delta\theta_2 = P'''\delta a_3 + Q'''\delta\beta_3 + R'''\delta r_3 + S'''\delta\theta_3 + T''' \pm {\cdot}000067$$

where P, Q, R . . . were obtained numerically, and the probable errors are expressed in terms of the Moon's radius, the geocentric value of the largest being 0″·06.

These equations were used to transform the linear equations

$$\delta\xi_2 = F(\delta a_2, \delta\beta_2, \delta\theta_2, \delta r_2) \qquad \delta\eta_2 = f(\delta a_2, \delta\beta_2, \delta\vartheta_2, \delta r_2)$$

found in § 3 into equivalent linear equations

$$\delta\xi_2 = F_1(\delta a_3, \delta\beta_3, \delta\vartheta_3, \delta r_3) \qquad \delta\eta_2 = f_1(\delta a_3, \delta\beta_3, \delta\vartheta_3, \delta r_3)$$

in which the coefficients are functions of the position of the point ξ, η, as well as of the constants P, Q, R . . .

With these equations measures made upon Plate II. could be used to determine the corrections to the constants of Plate III., and as Plate II. was taken a little after first quarter, Plate III. a little before third quarter, the two together show the whole disc, with a slight overlap near the central meridian.

But in order to find these corrections it was necessary to know the positions of a number of points on the Moon's surface, and it had already been shown (*Monthly Notices*, vol. lx. p. 184) that those previously found as "points of the first order" were not good enough for the purpose. It was at this stage that use was made of the places found at the telescope.

The available material consisted of the positions of *Mösting A*, from which all the others had been measured, 19 points within about 500″ of *Mösting A* measured by myself, two of which had been also measured by Professor Barnard, and the 8 points, all near the limb, measured by Dr. Franz. Two of these 8, *Aristarchus* and *Byrgius A*, were, in consequence of the brightness of the surrounding regions, too poorly defined to be measurable on the photographs. I had therefore a total of 26 points, of which 8 appeared on Plate II. only, 8 on Plate III. only, and 10 were shown on both plates. These were all the centres of regular circular formations. I had also measured the cones of *Herschel* and *Manilius*, but in consequence of the difficulty in locating the summit of a mountain I decided not to employ any points of this nature.

The selected points having been carefully measured on the photographs, the corresponding values of ξ, η were computed for each, as well as the coefficients of the different terms in the expressions for $\delta\xi$, $\delta\eta$, the approximate values of the plate constants being used for the purpose.

Equating the values of $\xi+\delta\xi$, $\eta+\delta\eta$ found from the photographs to the corresponding values of ξ, η found at the telescope, there were 72 equations for the four quantities δa_3, $\delta\beta_3$, δr_3, $\delta\theta_3$. But these were not all dealt with in one group.

§ 5. *Comparison of Constants obtained from Dr. Franz's Measures with those obtained from my own.*

The first point about which I was anxious to satisfy myself was as to the accordance between the positions which I had found and those measured by Dr. Franz. I had already found (*Monthly Notices*, vol. lx. p. 540) a satisfactory agreement between my own measures and measures of the same points by Professor Barnard, but in this case the distances measured had been under 160″. My own micrometer screw had begun to show signs of wear, evidenced by a want of constancy of the error of runs in different parts of the scale, and I felt anxious as to any possible effect of this upon the measures.

I therefore picked out the 60 conditional equations derived from the positions of *Mösting A* and of the points which I had measured myself, and from these determined the corrections to the plate constants.

I then dealt in the same way with the 16 equations obtained from the positions of *Mösting A* and of the points measured by Dr. Franz.

The following table shows the results of the comparison. The values of δa_3, $\delta\beta_3$, δr_3 are expressed first in terms of the Moon's radius as unit, and secondly in seconds of arc at mean distance of the Moon; $\delta\theta_3$ is expressed first in circular measure, and secondly in seconds of arc.

	δa_3	$\delta\beta_3$	δr_3	$\delta\theta_3$
Difference between absolute values of corrections found from the two groups of equations ...	·00023 = 0″·21	·00022 = 0″·21	·00030 = 0″·28	·00002 = ″4
P.E. from measures by S. A. S ...	·00005 = 0·05	·00005 = 0·05	·00015 = 0·14	·00015 = 31
P.E. from measures by J. F. ...	·00011 = 0·10	·00010 = 0·09	·00015 = 0·14	·00014 = 29

The first point to which attention was directed was that the differences between the values of δa_3, $\delta\beta_3$ were greater than the sum of the probable errors, whilst the probable errors from my own points were about half those from Dr. Franz's points. The fact that my values depended on nearly four times as many conditional equations would explain the difference in probable error, but the difference in the values found I attributed chiefly to the fact that the points which I had measured at the telescope were more clearly defined on the photographs than those which Dr. Franz had measured, so that the photographic measures of my points were more trustworthy than those of Dr. Franz's. It did not appear likely that the position of the centre as determined from my points alone would be subject to any systematic error, and, moreover, when the whole of the 72 conditional equations were solved in one group the probable errors of δa_3, $\delta\beta_3$ were ·000059 and ·000058 respectively, a little greater than those determined from my points alone. It therefore appeared

that the centre would be best determined by considering only the equations of the first group.

The want of definition of Dr. Franz's points upon the photographs would also affect the values of the radius and orientation derived from them; but this was compensated by their greater distance from the centre, and the probable errors from the two groups were practically the same. But in the normal equations for δr_3 the coefficient of δa_3 was nearly as great as that of δr_3. This was found to be due, as to *Mösting A* and the points which I had measured, to a relation between the libration and the position of the terminator in consequence of which the coefficients of δa_3, δr_3 retained the same sign in all the equations of the ξ group given by Plate II. As to the points measured by Dr. Franz the fact that four of them were on one side of the central meridian and only two of them on the other operated in the same way. The result was that the value found for δr_3 depended largely upon that assigned to δa_3, whilst the normal equation for δa_3 was such that the value of δa_3 was only slightly affected by that of δr_3. When this was noticed the normal equations in δr_3, $\delta\theta_3$ given by my points and those given by Dr. Franz's points were solved with the same values of δa_3, $\delta\beta_3$. The difference between the two values found for δr_3 was then reduced to ·00015 of the Moon's radius=0″·14. The difference in the scales derived from the two sets of measures amounted therefore to but little more than one part in 7,000, with which agreement I was quite satisfied, and from which it would appear that the wear of the screw had not been sufficient to introduce sensible error into the results.

The two values of $\delta\theta_3$ were practically coincident, though the probable errors show that this was partly fortuitous.

§ 6. *Final Solution of the Equations.*

Having decided that the whole 72 equations should be employed in the determination of $\check{c}r_3$, $\check{c}\theta_3$, whilst the values of $\check{c}a_3$, $\check{c}\beta_3$ should depend upon the group of 60 only, the proper course would have been to express δr_3, $\check{c}\theta_3$ as functions of $\check{c}a_3$, $\check{c}\beta_3$ from the 72 equations, to substitute these values in the group of 60, and to solve the resulting equations for δa_3, $\delta\beta_3$. This, however, would have involved a considerable addition to the labour of computation, which was already very great, whilst the effect upon the solution would have been almost imperceptible. The greatest difference between the solutions obtained entirely from one set or entirely from the other set of equations amounted only to 0″·2. I therefore compromised matters by taking the two normal equations in $\check{c}a_3$, $\check{c}\beta_3$ from the group of 60 conditional equations, the two in δr_3, $\check{\delta}\theta_3$ from the whole group of 72, and accepted as final the values resulting from their simultaneous solution.

Having determined these the corrections δa_2, $\delta\beta_2$, δr_2, $\delta\theta_2$ were given by the equations given at the beginning of § 4, and a set of constants was determined which would enable the standard coordinates to be found for any point measurable on either plate.

It should be noted that the coordinates of the 10 points measured at the telescope and shown on both plates enter each into two conditional equations, being equated separately to the corresponding coordinate from each photograph; but those of the 16 points shown on one plate only enter each into only one conditional equation, and so have less weight in the normal equations than the others. But I believe that the principal errors at present are in the photographic measures, and that consequently the course adopted is justifiable.

The advantages which would seem to be secured by expressing the constants of one plate in terms of those of the other are, first that a greater number of conditional equations is obtained than could be secured from either plate alone, and secondly that the use of two plates taken under different librations and oppo-

Comparison between Places derived from Paris Plates II. and III., Professor Barnard and

	Values of ξ.					
	Plate II.	Plate III.	II.–III.	Mean of II. & III.	Telescopic.	Photographic – Telescopic.
Lilius (sm. crater)*	+·0617	+·0620	−·0003	+·0618	...	...
Licetus (sm. crater)†	+·0231	+·0221	+ 10	+·0226	...	...
Fabricius K	+·4666	...	...	...	+·4664	+·0002
Licetus H	+·0383	+·0381	+ 2	+·0382	...	...
Stöfler *f*	+·0641	+·0633	+ 8	+·0637	...	...
Nicolai A	+·2966	...	...	...	+·2960	+ 6
Stöfler K	+·0567	+·0566	+ 1	+·0567	...	...
Orontius *d*	−·0829	−·0829	0	−·0829	...	...
Walter *a*	+·0093	+·0090	+ 3	+·0091	...	...
„ (sm. crater)‡	−·0025	−·0028	+ 3	−·0026	...	...
Hesiodus B	...	−·2680	...	...	−·2671	− 9
Purbach A	−·0295	−·0296	+ 1	−·0295	...	...
Nicollet	...	−·2003	...	...	−·1998	− 5
Thebit A	−·0789	−·0789	0	−·0789	−·0792	+ 3
Abenezra *b*	+·1638	+·1639	− 1	+·1638	+·1635	+ 3
Arzachael A	−·0247	−·0247	0	−·0247	...	...
Airy (sm. crater)§	+·0743	+·0746	− 3	+·0745	...	...
„ A	+·1277	+·1279	− 2	+·1278	+·1276	+ 2

* The most westerly of three confluent craters of which the most easterly is *b*.

† A small round crater west of *f* and *d*.

‡ The isolated crater on the south-east part of the floor.

§ To the east of Airy, almost in contact with the wall.

site illuminations tends to eliminate any systematic error depending upon either of these conditions. It is perhaps open to question whether the same amount of labour spent upon measuring and reducing several different plates independently, and taking the means of the resulting places, would not have given a closer approximation to the true values of the coordinates; but the greater part of the work was performed in the endeavour to obtain absolute places from a comparison of two photographs only, without appealing to telescopic measures at all. It was only when this failed that the method finally adopted suggested itself, and I think that the labour spent upon the reductions from that period has yielded an adequate return.

In the following table I give a comparison of the places finally obtained from the two plates with each other, and with those obtained at the telescope. The suffixes as before refer to the Plates II., III. respectively. The column headed "Authority" refers to the telescopic measures, and the initial B. denotes Professor Barnard, F. Dr. Franz, and S. myself.

Heliometer Measures by Dr. Franz, and Filar Micrometer Measures by by S. A. Saunder.

Values of η.						
Plate II.	Plate III.	II.-III.	Mean of II. & III.	Telescopic.	Photographic - Telescopic.	Authority.
−·7960	−·7964	+·0004	−·7962	...	...	
−·7285	−·7287	+ 2	−·7286	...	...	
−·7197	...	...	...	−·7202	+·0005	F.
−·7182	−·7182	0	−·7182	...	...	...
−·6774	−·6773	− 1	−·6773	...	...	...
−·6742	...	...	...	−·6749	+ 7	F.
−·6352	−·6352	0	−·6352	...	...	...
−·6345	−·6345	0	−·6345	...	...	...
−·5935	−·5935	0	−·5935	...	...	...
−·5546	−·5545	− 1	−·5545	...	...	...
...	−·4556	...	...	−·4555	− 1	S.
−·4405	−·4406	+ 1	−·4405	...	...	...
....	−·3725	...	...	−·3730	+ 5	S.
−·3677	−·3673	− 4	−·3675	−·3674	− 1	S.
−·3550	−·3548	− 2	−·3549	−·3552	+ 3	S.
−·3903	−·3903	0	−·3903	...	...	...
−·3025	−·3024	− 1	−·3025	...	...	...
−·2926	−·2926	0	−·2926	−·2929	+ 3	S.

	Values of ξ.					
	Plate II.	Plate III.	II.–III.	Mean of II. & III.	Telescopic.	Photographic – Telescopic.
Gassendi *z*	...	−·6522	...	...	−·6525	+ 3
Alpetragius B	−·1152	−·1156	+ 4	−·1154	...	...
Lubiniezky B	...	−·3864	...	...	−·3863	− 1
Dollond	+·2456	...	...	...	+·2458	− 2
Ptolemæus A	−·0139	−·0140	+ 1	−·0140	−·0142	+ 2
„	„	„	„	„	−·0139	− 1
Hailey	+·0999	+·0994	+ 5	+·0996	...	...
Hipparchus C	+·1422	+·1426	− 4	+·1424	+·1423	+ 1
Euclides	...	−·4892	...	...	−·4886	− 6
Hipparchus L	+·1560	+·1565	− 5	+·1563	...	...
„ G	+·1288	+·1292	− 4	+·1290	+·1287	+ 3
„ *n*	+·0873	+·0871	+ 2	+·0872	...	...
Mösting A	−·0904	−·0904	0	−·0904	−·0900	− 4
Hipparchus H	+·0526	+·0528	− 2	+·0527	...	...
Gambart A	...	−·3209	...	...	−·3210	+ 1
Triesnecker B	+·0068	+·0067	+ 1	+·0067	+·0072	− 5
„	„	„	„	„	+·0073	− 6
Cayley	+·2602	...	...	...	+·2603	− 1
Murchison A	+·0199	+·0199	0	+·0199	...	...
Hortensius	...	−·4660	...	...	−·4662	+ 2
Sosigenes *a*	+·3144	...	...	...	+·3145	− 1
Bode B	−·0531	−·0528	− 3	−·0529	−·0529	0
„ A	−·0201	−·0200	− 1	−·0201	−·0199	− 2
Proclus	+·7022	...	...	...	+·7022	0
Macrobius *a*	+·6107	...	...	...	+·6103	+ 4
Conon	+·0324	+·0326	− 2	+·0325	...	...
Bessel	+·2865	...	...	...	+·2856	+ 9
Aratus	+·0727	+·0728	− 1	+·0728	...	...
Archimedes A	−·0983	−·0983	0	−·0983	...	...
„ *c*	−·0221	−·0223	+ 2	−·0222	...	...
„ *b*	−·0268	−·0276	+ 8	−·0272	...	...
Kirch	−·0754	−·0755	+ 1	−·0754	...	...
Cassini *b*	+·0521	+·0520	+ 1	+·0521	...	...
„ A	+·0635	+·0635	0	+·0635	...	...
„ (small crater)*	+·0495	+·0492	+ 3	+·0494	...	...
Piazzi Smyth	−·0416	−·0418	+ 2	−·0417	...	...
Sharp A	...	−·4560	...	...	−·4566	+ 6

* Just outside Cassini to the north-east.

Values of η.						
Plate II.	Plate III.	II.–III.	Mean of II. & III.	Telescopic.	Photographic – Telescopic.	Authority.
...	−·2829	...	...	−·2833	+ 4	F.
−·2604	−·2605	+ 1	−·2605	...	...	...
...	−·2516	...	...	−·2515	− 1	S.
−·1817	...	...	...	−·1817	0	S.
−·1480	−·1480	0	−·1480	−·1479	− 1	B.
,,	,,	,,	,,	−·1478	− 2	S.
−·1390	−·1394	+ 4	−·1392	...	...	...
−·1285	−·1285	0	−·1285	−·1285	0	S.
...	−·1279	...	...	−·1283	+ 4	S.
−·1190	−·1192	+ 2	−·1191	...	...	...
−·0872	−·0872	0	−·0872	−·0875	+ 3	S.
−·0843	−·0841	− 2	−·0842	...	...	...
−·0558	−·0556	− 2	−·0557	−·0556	− 1	F.
−·0386	−·0382	− 4	−·0384	...	...	...
...	+·0167	...	...	+·0170	− 3	S.
+·0205	+·0204	+ 1	+·0204	+·0205	− 1	B.
,,	,,	,,	,,	+·0206	− 2	S.
+·0690	...	...	...	+·0690	0	S.
+·0697	+·0697	0	+0·697	...	...	...
...	+·1130	...	...	+·1128	+ 2	S.
+·1353	...	...	...	+·1349	+ 4	S.
+·1523	+·1520	+ 3	+·1521	+·1525	− 4	S.
+·1564	+·1568	− 4	+·1566	+·1569	− 3	S.
+·2772	...	...	...	+·2770	+ 2	F.
+·3342	...	...	...	+·3345	− 3	F.
+·3697	+·3693	+ 4	+·3695	...	...	...
+·3701	...	...	...	+·3704	− 3	S.
+·4004	+·4003	+ 1	+·4003	...	...	...
+·4699	+·4699	0	+·4699	...	...	...
+·5238	+·5237	+ 1	+·5238	...	...	...
+·5702	+·5697	− 5	+·5699	...	...	...
+·6321	+·6321	0	+·6321	...	...	...
+·6422	+·6422	0	+·6422	...	...	...
+·6488	+·6489	− 1	+·6488	...	...	...
+·6601	+·6603	− 2	+·6602	...	...	...
+·6671	+·6668	+ 3	+·6670	...	...	...
...	+·7380	...	...	+·7376	+	F.

§ 7. *Discussion of Results obtained.*

It is satisfactory to note that no two positions of the same point are separated by as much as a second of arc, though in two or three cases this limit is approached. Some part of the discordances found may be real, depending, as has been shown by Dr. Franz, upon the elevation above or depression below the surface of the sphere most nearly representing the figure of the Moon. But it must be borne in mind that concordance between the places derived from the two photographs does not prove the accuracy of those places, otherwise the attempt to determine absolute places by securing such concordance would have succeeded. The real test is to be found in the agreement of places derived from the photographs with those obtained at the telescope.

The mean distance between these positions for the six points measured by Dr. Franz is $0''\cdot53$, these points being shown on only one plate each. For the nineteen points measured by myself there are twenty-eight photographic measures on the two plates, and the mean of the twenty-eight divergences is $0''\cdot38$, whilst for the ten points which have been measured on both plates the mean divergence between the telescopic and the mean photographic places is $0''\cdot32$. The mean divergence for the eighteen points measured on Plate II. is $0''\cdot37$; for the eighteen points measured on Plate III. it is $0''\cdot42$.

The greater divergence exhibited by the six points measured by Dr. Franz is, I think, chiefly due to the fact that they are not well defined on the photographs. There is not one of them that I should have selected as a really satisfactory point for accurate measurement on these particular plates, and I am pleased to find that the divergence is no greater. This I think may be taken as a satisfactory indication that the scale and orientation are well determined, so that divergences do not sensibly increase as we recede from the centre. I think also it may be fairly concluded from the whole comparison that the position of a point on any part of the surface may be determined from a single photograph on which it is well defined with an error less than one second of arc.

In estimating the advance thus made towards the accurate determination of selenographic positions it must be remembered that we are not dealing with stellar points; that in the most favourable cases, such as those here considered, we have to estimate the centre of a formation seldom less than 5″ or 6″ in diameter, and frequently more, subject to all the confusion produced by a transition from dazzling brightness to the blackest shade, and that therefore it is not to be expected that the position of a lunar formation should be capable of as accurate determination as that of a fixed star. I may perhaps be pardoned if I again call attention to the fact that the mean

distance between two positions of the same point found by Mädler and Lohrmann respectively, as determined from the eleven points measured as "points of the first order" not less than five times by each, was 5″·2, or almost exactly ten times the average discordance between the six points measured by Dr. Franz and my own determination of their positions, each from one photograph only, under conditions which were certainly not too favourable to the photographs.

The accuracy now attained is, I think, sufficient for such purposes as the preparation of large-scale maps, the computation of the Sun's altitude as required for determining the heights of mountains, and for the great problem to which these are subsidiary, the detection of possible changes on the surface.

But of greater importance than the increase of accuracy in the determination of a few isolated points is the enormous increase in the number of points which can now be accurately measured. With the old methods the computations required for the determination of "points of the first order" were so tedious that rougher methods were devised for determining points of the "second" and "third order," as they were called. These carried with them all the errors of the points of the first order from which they were measured, whilst introducing others due to the methods adopted for the reduction.

Beer and Mädler's map was based on 105 points of the first order, Schmidt's on 157. As a foundation for the outline maps which are being issued by the British Astronomical Association, I have already measured seventy-four points on an area equal to ·014 of the projection of the visible hemisphere (*B.A.A. Memoirs*, vol. x., 5th Report of the Lunar Section). This area is the corner of the S.W. quadrant near the centre of the disc, and includes the whole of *Hipparchus* and portions of the neighbouring formations. It was selected as a suitable region for the commencement of a scheme for remapping the whole surface, and if this is well taken up it is proposed to gradually extend the area. More points might have been measured on either of the plates, but I preferred to limit myself to those which could be measured with a fair approach to accuracy on both, and I have every reason to believe that these seventy-four points are determined with errors very little in excess of those in the list now given. With more photographs it will be possible to measure other points in the same area, as well as to increase the accuracy of those already measured. Some regions will perhaps give an even closer aggregation of measurable points, whilst the large seas will probably not give so many. But the density of distribution on the area already measured corresponds to more than 5,000 on the whole hemisphere. These will again serve as points of reference by which to fix the still more numerous points not at present shown in the photographs, but easily seen in a small telescope, and in which we are most likely to detect evidences of those changes which have been

so strongly suspected by the most trustworthy seleniographers, and so ruthlessly rejected by the majority of the writers of astronomical text-books.

§ 8. *Focal Length of the Paris Telescope and Scale of the Photographs.*

In § 13 of my previous paper I gave the values found for the focal length of the photographic object glass of the Paris great Equatorial Coudé from the measures then made. These were vitiated by an erroneous assumption as to the size of the réseau square employed, which was really 5·040 mm., instead of 5·000 mm., as well as by the errors attendant upon limb measures. With the scale values now adopted it appears that a side of the réseau square on Plate II. corresponds to 57″·55, and on Plate III. to 57″·59. The values which I obtain for the focal length of the telescope are 18·064 m. on 1899 February 18, and 18·052 m. on 1895 September 9. The temperatures on these two nights were probably very different, but the difference of focal length is of the opposite sign to that which would be expected from this cause alone.

§ 9. *Conclusion.*

The computations have been almost entirely performed with a "Brunsviga," which is admirably adapted, not only for computing expressions of the form $Ax+By+Cz$, of which a large part of the work has consisted, but also for forming the normal equations in a least square solution, and for the eliminations according to Gauss' method. The computations have been carried to not less than five places throughout; where there appeared to be special danger of cumulative error more figures have been retained. The values of ξ, η given by the photographic plates have been doubly computed—first by applying the differential corrections to the values computed with the approximate plate constants, and secondly directly from the measured coordinates with the corrected values of the plate constants.

I should hope that the positions now obtained are sufficient both in number and in accuracy to allow of the determination of the constants of a plate by the method proposed by Professor Turner, and described in § 9 of my previous paper, by which a considerable reduction is effected in the amount of computation required. My next step will be to endeavour to reduce a plate in this way. If I am successful progress in the future will be more rapid than it has been in the past.

The plates, as stated in my previous paper, are positive copies on glass, kindly made for me by Mr. Bellamy, of the University Observatory, Oxford, from Paris negatives, for which I am indebted to the generosity of M. Loewy.

The photographic measures were made with an astrographic micrometer of the pattern in use at Greenwich and Oxford, the property of the University Observatory, Oxford, and kindly lent me by Professor Turner, who has not only placed the resources of the Observatory at my disposal, but has supplemented them with a large share of personal advice and assistance, for all of which my most hearty thanks are due.

§ 10. *Comparison of Results with those in Breslau "Mitteilungen," Vol. I.*

Since this paper was written copies have been received in England of the first volume of the *Mitteilungen* of the Breslau Observatory, in which Dr. Franz gives the places of 150 lunar formations as determined by the measurement of five Lick photographs, and it has been with great interest that I have compared his methods and results with my own. In what may be considered the essentials of the methods we agree: we have both made our work independent of direct measures of the limb, and have determined the constants of our plates by comparing the photographic measures of a number of points with the positions of the same points determined by telescopic measures from *Mösting A*; but in the details there are many points of difference.

Professor Franz's telescopic measures have been made with the heliometer, my own with the filar micrometer, the bisection of two formations with the latter instrument being an entirely different operation from the superposition of their images with the former. Dr. Franz has been able to measure eight points near the limb. I have been obliged to measure a greater number nearer the centre, although I have been able to avail myself to a limited extent of his published results, as explained above.

The photographs which Dr. Franz has measured have all been taken near the time of full Moon, so that a great number of the objects measured have appeared only as light spots, no detail being visible. My photographs show but little more than half the disc illuminated, and I have not measured a crater unless a considerable portion of the wall could be made out.

In measuring the photographs Dr. Franz has bisected the craters with a thread moved by a screw, the reading of which, added to that of an accurate scale on which the microscope was carried, gave the measured coordinate. I have measured with a réseau and a graduated cross in the eyepiece, the setting being made either by getting equal readings on opposite arms where they cut the crater walls, or by setting the crater symmetrically in one of the squares formed by the longer (fifth or tenth) division lines.

The reductions have also been performed by quite independent methods.

It would thus seem unlikely that the two sets of places should be affected by the *same* systematic errors.

In order to compare the results it was necessary for me to give relative weights to my own photographic and telescopic measures. I find that the probable error of a coordinate measured on one photographic plate is 0″·09, as determined from the divergences between the two plates. The corresponding probable error for the mean of four telescopic measures was found in § 2 to be 0″·10. But it has already been pointed out that the measure of the discordance between the two plates may give too high an estimate of the value of the absolute results obtained, since errors in the constants give systematic errors in the results, and the method of solution renders it probable that these will be in the same direction in the two plates. I have therefore given to a coordinate obtained from one plate half the weight of the mean of four telescopic measures. I may note in passing that Dr. Franz gives no weight to his photographic measures as compared with those made with the heliometer.

In addition to *Mösting A* and the six points already referred to, there are seventeen points that Dr. Franz and I have both measured. In the following table I compare the positions which result from this combination of my own measures of these points with those found by Dr. Franz :—

	Values of ξ.			Values of η.		
	J. F.	S. A. S.	F.-S.	J. F.	S. A. S.	F.-S.
Nicollet	−·1997	−·2000	+·0003	−·3732	−·3728	−·0004
Thebit A	−·0794	−·0791	− 3	−·3677	−·3674	− 3
Airy (sm. crater)	+·0746	+·0745	+ 1	−·3028	−·3025	− 3
Airy A	+·1278	+·1277	+ 1	−·2930	−·2928	− 2
Lubiniezky B	−·3859	−·3863	+ 4	−·2520	−·2515	− 5
Ptolemæus A	−·0138	−·0140	+ 2	−·1480	−·1479	− 1
Hipparchus C	+·1422	+·1423	− 1	−·1288	−·1285	− 3
Euclides	−·4880	−·4888	+ 8	−·1287	−·1282	− 5
Hipparchus G	+·1289	+·1288	+ 1	−·0874	−·0874	0
Gambart A	−·3211	−·3210	− 1	+·0167	+·0169	− 2
Cayley	+·2599	+·2603	− 4	+·0688	+·0690	− 2
Sosigenes *a*	+·3139	+·3145	− 6	+·1351	+·1350	+ 1
Bode B	−·0530	−·0529	− 1	+·1520	+·1523	− 3
„ A	−·0198	−·0200	+ 2	+·1562	+·1568	− 6
Bessel	+·2855	+·2859	− 4	+·3699	+·3703	− 4
Aratus	+·0724	+·0728	− 4	+·4005	+·4003	+ 2
Archimedes A	−·0984	−·0983	− 1	+·4698	+·4699	− 1

In no case does the discordance between two positions amount to 1″ of arc (geocentric). The only formation for which this value is approached is *Euclides*, which was not well defined on

Dr. Franz's photographs. This one may conjecture to have been due to the brightness of its surroundings.

The comparison reveals a systematic difference of ·0002 in the ordinates, but is consistent with the supposition that the differences in the abscissæ are accidental.

This difference in the ordinates is slightly increased when the comparison is made between Dr. Franz's positions and my telescopic positions only, whilst it would have practically disappeared from the photographic measures had I adopted the ordinate of the centre derived in § 5 from the photographic measures of the six points measured with the heliometer by Dr. Franz.

The result therefore justifies my rejection of these photographic measures so far as the abscissa of the centre is concerned, but gives reason for suspecting a real systematic difference of about 0″·2 in the ordinates between Dr. Franz's positions found with the heliometer and mine found with the filar micrometer.

The mean geocentric distance between the positions of the same point, as found by Dr. Franz and myself, is 0″·39, or less than one-thirteenth of the corresponding mean distance between positions found by Lohrmann and Mädler. There was also a systematic difference of a different kind between the ordinates found by these observers about fifteen times as great as that between Dr. Franz and myself, Lohrmann placing his points further from the equator than Mädler.

That small systematic differences should appear is not surprising. Dr. Franz calls attention to their existence between different parts of his own work, and I have already noted the same feature with regard to my work in the *Fifth Report of the Lunar Section of the British Astronomical Association.*

It says much for the general accuracy of the method that both these and the accidental differences should be as small as they are; and it is a great gratification to me to find my own work in such close agreement with that of one who has, I believe, given more attention to selenographic measurements than any other living astronomer, and to whom we owe the best determinations both of the physical libration and of the figure of the Moon.

Recent Observations of the Position of Nova Aurigæ with the 40-inch Telescope of the Yerkes Observatory. By E. E. Barnard.

Shortly after the announcement of Dr. Anderson's discovery of *Nova Aurigæ* in 1892 February Mr. Burnham made a careful set of measures of its position with reference to some thirteen stars near it.

The results of this work are given by him in a paper in

Monthly Notices for 1892 April. In the same publication for 1892 December he gives his observations of the brightness of the *Nova* as it slowly faded out. These observations were made with the 36-inch equatorial of the Lick Observatory. From March 13 of that year, when his determinations of magnitude began, until April 26, when proximity to the Sun prevented further work, the star had diminished from the 8th to the 16th magnitude. In Mr. Burnham's opinion it could not have been seen with the 36-inch for more than one week longer even had the star been favourably placed for observation. After March 13 the decrease in light was essentially uniform at the rate of 0·18 magnitude a day.

In August of the same year the star had brightened up again to between the 10th and 11th magnitudes, and had undergone a remarkable physical change, as shown by both visual and spectroscopic observations, indicating that the *Nova* then possessed the characteristics of a planetary nebula.

This star has faded considerably in the past few years, and is now of about the 13th magnitude.

In *Astronomische Nachrichten*, 3143, 3238, and 3279, I have given micrometer measures of the *Nova* with respect to two of Mr. Burnham's comparison stars, E and F of his diagram in *Monthly Notices* for 1892 April. These measures showed that in the two years during which the star was under observation no appreciable change occurred in its position, there being no evidence of parallax or proper motion, implying an enormous distance from the Earth.

My own measures were also in close agreement with those of Mr. Burnham.

The *Nova* has been examined a few times with the 40-inch, and I have in the past winter secured some further measures of its position with the large telescope. These show that no change has occurred in its place in the past eight years.

Mr. Newall has questioned the nebulous condition of the star, though the spectroscope has shown that it has the spectrum of a planetary nebula.

At the second appearance in 1892, when it had brightened up from the 16th, in May, to the 10th or 11th magnitude in August, it was found to have undergone a change both in appearance and in its spectrum. It had become bluish-white in colour, though in the earlier stages of its first appearance it was yellowish, and had seemed to grow redder as it diminished in brightness. It had also the appearance of a nebulous star.

In the present observations with the 40-inch the star was much fainter than at the measures with the 36-inch. On 1900 November 3 a direct estimation made it of the $13\frac{1}{2}$ magnitude, while from a comparison with the stars near it, whose magnitudes had been determined by Mr. Burnham, I found it to be of the 13·0 magnitude on Burnham's scale of magnitudes. On this date a determination of the difference of focus between the *Nova*

and the star F made the focus of the former 0·3 inch further out than for F. It was not as well defined as the stars.

During these observations the position of the *Nova* was again measured with reference to E and F on some five nights. The results are given as follows :—

Positions of Nova Aurigæ in 1900.

A and F.

Nov.	3	1900·842	32°46	84″96
	5	·847	32·52	...
	22	·894	32·73	84·87
	26	·905	32·64	84·93
Dec.	8	·937	32·75	85·09
		1900·885	32·62	84·96

A and E.

Nov.	3	1900·842	323°28	74″49
	5	·847	323·04	...
	22	·894	323·34	74·35
	26	·905	323·16	74·63
Dec.	8	·937	323·22	74·59
		1900·885	323·21	74·51

On November 5 clouds prevented distance measures. November 22 the measures were hurriedly made.

Following are the means of the different seasons' measures of the *Nova* and these two stars. Those of 1892, 1893, and 1894 were made with the 36-inch of the Lick Observatory. Those of 1900 were made with the 40-inch of this observatory.

Means for each Season of Observation.

A and E (E = 12ᵐ).

1892·9	323°38	74″58	16 nights.
1893·9	323·43	74·51	14 „
1894·9	323·41	74·66	3 „
1900·9	323·21	74·51	5 and 4 „
1895·6	323·377	74·543	Weighting by number of nights

A and F (F = 10·5ᵐ).

1892·9	32°63	84″94	18 nights.
1893·9	32·89	84·91	8 „
1894·9	32·63	84·94	3 „
1900·9	32·62	84·96	5 and 4 „
1895·6	32·675	84·927	Weighting by number of nights.

If now we compare the means for each year with the means of all the measures of the different years, we shall have the following:

Yearly Means Compared with the Means of all the Measures.

	A and F.			A and E.	
	°	″		°	″
1892	+0·045	−0·009	1892	−0·003	−0·037
1893	−0·145	+0·038	1893	−0·053	+0·037
1894	+0·045	−0·013	1894	−0·033	−0·114
1900	+0·055	−0·036	1900	+0·167	+0·031

These are in satisfactory agreement and show no certain change in the position of the *Nova*. They also show, as has been found in other measures, especially in those of the fifth satellite of *Jupiter*, that the same observer using the 36-inch of the Lick Observatory and the 40-inch of the Yerkes Observatory experiences no personality due to the different instruments, the measures made with one instrument being in perfect harmony with those made with the other.

The measures made by Mr. Burnham and given in *Monthly Notices* for 1892 April are, after correcting an error in the mean for the distance AE from 74·24 to 74″·32:

Mr. Burnham's Measures of the Nova.

	A and E.		
1892·14	323° 60	74″·32	3 nights.
	A and F.		
1892·12	32°·38	85″·05	4 nights.

These give the following differences from my observations:

A and E.		A and F.	
−0°·22	+0″·22	+0°·29	−0″·12

These are, considering the faintness of the objects and the distances measured, in as close agreement as would be expected from different observers. It is evident that further measures of this object for many years to come would be useless.

In looking up references to *Nova Aurigæ* the following corrections have been noted.

In *Astronomische Nachrichten* 3238, p. 391, F. Renz gives some measures of these objects. His comparison stars were E and F. In his measures the star F is put in the wrong quadrant with reference to the *Nova*, the position angle being given 212. It should be 32°.

In *Monthly Notices* for 1892 April the scale given at the bottom of Mr. Burnham's diagram is wrong. On this scale

the figures read 0″, 40″, 80″. To correspond with the diagram they should be 0″, 80″, 160″. In the same paper, at p. 436, a reference is made to *Astronomische Nachrichten* 3070: this is a typographical error for 3076.

Yerkes Observatory, Williams Bay, Wisconsin:
1901 *July* 29.

Further Observations of Nova Aurigæ in 1901.

By E. E. Barnard.

Nova Aurigæ has been observed on two nights this year, and on each occasion its light was estimated in terms of the comparison stars used by Mr. Burnham in 1892. The comparisons were made with the stars B, E, *e*, G, H and J.

The result from all these made the *Nova* 12·7 magnitude on this scale.

Direct estimates on the two dates made the magnitude 13·0 and 12·9 respectively.

I also made independent estimates of the magnitudes of the comparison stars. They are:

		B	C	E	*e*	F	G	H	J	M	*m*
Oct.	21	13·5	15·0	11·8	13·2	10·0	11·7	12·0	12·0	12·0	12·0
	22	—	15·0	12·1	14·0	10·0	12·0	12·3	12·4	12·5	—
		13·5	15·0	11·9	13·7	10·0	11·8	12·1	12·2	12·2	12·0

Of these stars Mr. Burnham has given the following magnitudes:

B 14·8 C 15·2 E 11·7 *e* 13·2 F 10·4 G 11·5 H 11·8 J 12·7
M 13·2 *m* 13·8.

His estimate of the brightness of B was doubtless influenced by the proximity of the greater brightness of the *Nova* in the spring of 1892.

In my estimates of the magnitudes of M and *m* no note was made for their relative brightness. My recollection is that M was somewhat the brighter of the two.

Under the best conditions the *Nova* has not appeared well-defined when in the best focus. There is a slight haziness about it suggestive of a slightly nebulous star.

1901 *October* 29.

On the Variation of T Centauri. By Alex. W. Roberts, D.Sc,

The variation of the star *T Centauri* (Chandler, 4896), R.A. $13^h\ 36^m\ 2^s$ (1900), Dec.$-33°\ 5'{\cdot}5$, was discovered in 1894 by Colonel Markwick, and independently the same year by Professor Pickering.

The Harvard notification of its discovery is given in the *Astronomische Nachrichten*, No. 3269, p. 72, and that of Colonel Markwick in the *Journal of the British Astronomical Association*, vol. v., p. 247. As far back as 1890, however, its variation was suspected by Kapteyn from an examination of the Cape Photographic Durchmusterung plates. His note on the variable magnitude indicated by the Cape Photographs is contained in *Astronomische Nachrichten*, No. 2987.

The following papers on the variation of *T Centauri* have already appeared in the *Monthly Notices*—

Vol. lvi., p. 35 (Markwick)
„ lvi., p. 347 (Roberts)
„ lvi., p. 500 (Roberts)
„ lviii., p. 513 (Markwick)

in which the nature and period of the star's variation are set forth.

Three years have now elapsed since the last of the four foregoing papers was published, and although observations made during these years have not in any way altered the general conclusions come to then, I think sufficient data have accumulated to enable a very accurate determination of the chief elements of the star's variation to be made.

In arriving at a determination of the period of *T Centauri*, or of any other long-period variable, it should be remembered that the possibility of the period being subject to a secular inequality is not unlikely. Because of this it is as well to include in the investigation only such maxima and minima as have been determined from a full-light curve, or at least from observations so situated on the light curve that they indicate, within a certain margin of error, the date of maximum or minimum brightness.

I have in other papers called attention to the uncertainty which always attaches to isolated meridian observations of magnitude; they are indeed of very little value as an aid to a definitive determination of light period unless the interval which separates the several dates is sufficiently great to compensate for the uncertainty in brightness.

If, of course, a meridian observation is manifestly taken near a maximum or minimum phase, then its value, as an aid to a

determination of the period of the star, is considerably enhanced; but even in this case, the range in brightness is usually so irregular, amounting in the case of *T Centauri* to two magnitudes, that there is always some slight uncertainty with regard to a maximum or minimum date estimated from meridian observations alone.

I propose therefore in the present investigation to base a determination of the period of *T Centauri* upon: (1) Recent systematic observations of magnitude; (2) All available data.

The first portion of the investigation will yield elements which satisfy present observations. If the period of the star is subject to secular inequality, these elements may not satisfy more remote observations.

In the following two series, Tables I. and II., are given the various maxima and minima determined rigorously during the past six years.

All the Lovedale observations were made with a 1-inch telescope, except where the star was passing through its maximum phase. Its brightness then allowed naked-eye estimates to be made.

TABLE I.

Determinations of Maxima.

Rotation No.	Date.	Julian Day. J	Mag. m	Observer.
1	1895 June 8	2413353	5·3	Markwick
2	June 10	2413355	5·8	Roberts
3	Sept. 10	2413447	6·0	,,
4	1896 March 8	2413627		Tebbutt
5	March 10	2413629	5·4	Roberts
6	June 16	2413727	6·0	,,
7	June 18	2413729	6·4	Markwick
8	Sept. 3	2413806	5·7	Roberts
9	1897 June 1	2414077	6·2	Markwick
10	1898 June 3	2414444	6·6	,,
11	Sept. 1	2414534	5·9	Roberts
12	1899 Feb. 25	2414711	5·2	,,
13	June 3	2414809	6·2	,,
14	Aug. 28	2414895	5·5	,,
15	1900 Feb. 25	2415076	6·0	,,
16	May 24	2415164	5·6	,,
17	Aug. 25	2415257	6·1	,,
18	1901 May 23	2415528	5·9	,,
19	Aug. 22	2415619	5·8	,,

TABLE II.

Determinations of Minima.

Rotation No.	Date.	Julian Day. J	Mag. m	Observer.
1	1895 April 26	2413310	9·0	Roberts
2	April 27	2413311	10·0	Markwick
3	July 30	2413405	8·0	Roberts
4	1896 April 26	2413676	8·9	,,
5	April 30	2413680	9·9	Markwick
6	July 24	2413765	8·7	Roberts
7	1898 April 18	2414398	9·2	Markwick
8	1899 April 10	2414755	8·9	Roberts
9	July 13	2414849	8·6	,,
10	1900 April 12	2415122	7·4	,,
11	July 13	2415214	8·3	,,
12	1901 April 10	2415485	7·4	,,
13	July 12	2415578	8·4	,,

Let now the following values be considered :

$P + \Delta p$ = period of variation ;

$T_M + \Delta t_M$ = epoch of maximum ;

$T_m + \Delta t_m$ = epoch of minimum ;

m = annual amount of secular variation of period ;

E = number of periods, reckoning from the epoch ;

J = Julian day of observation as given in column 3 of Tables I. and II.

Then it is evident that the following equations represent the relation of the various quantities to one another :

With regard to Table I. :

$$(T_M + \Delta t_M) + E\{(P + \Delta p) + \frac{E}{2}m\} = J$$

that is,

$$\Delta t_M + E\Delta p + \frac{E^2}{2}m = \{J - (T_M + EP)\} \ldots \qquad \ldots (1)$$

and with regard to Table II.,

$$\Delta t_m + E\Delta p + \frac{E^2}{2}m = \{J - (T_m + Ep)\} \ldots \qquad \ldots (2)$$

We readily obtain from Tables I. and II. the following approximate values of T_M, T_m and P,

$$T_M = 2415075^J,$$
$$T_m = 2415033^J,$$
$$P = 90^d.4.$$

With these assumed values and the values of J contained in column 3, we form equations of condition of the type indicated in (1) and (2).

It is not necessary to burden the paper with the statement of these thirty-two equations, or with the several steps in their solution.

The final result is as follows :

	d.
$\Delta t_M =$	$+1.1$
$\Delta t_m =$	-1.0
$\Delta p =$	$+0.07$
$\Delta m =$	0.000

This gives as the final elements of *T Centauri* for the year 1901 :

Epoch of maximum	$= 2415076.1$
Epoch of minimum	$= 2415032.0$
M − m	$= 44^d.1$
Period	$= 90^d.47$

The value of *m* obtained from the equations indicates that for the six years 1895–1901 the period of *T Centauri* was constant. We must not however infer from this that the period is always constant. This does not follow.

With the above corrected elements we now compute theoretical dates for comparison with the observed dates. This comparison is given in the following tables. Column 2 gives the values of E at the date of observation, column 3 the observed date ; column 4 the computed date, and column 5 the residual (O − C).

TABLE III.

Maxima Dates.

Rotation No.	E.	Julian Day. J	Computed Max. J	O−C. d
1	−19	2413353	2413357.2	−4.2
2	19	2413355	2413357.2	−2.2
3	18	2413447	2413447.6	−0.6
4	16	2413627	2413628.6	−1.6
5	16	2413629	2413628.6	+0.4
6	15	2413727	2413719.1	+7.9

Rotation No.	E.	Julian Day. J	Computed Max. J	O−C. d
7	− 15	2413729	2413719·1	+9·9
8	14	2413806	2413809·5	−3·5
9	11	2414077	2414080·9	−3·9
10	7	2414444	2414442·8	+1·2
11	6	2414534	2414533·3	+0·7
12	4	2414711	2414714·2	−3·2
13	3	2414809	2414804·7	+4·3
14	− 2	2414895	2414895·2	−0·2
15	0	2415076	2415076·1	−0·1
16	+ 1	2415164	2415166·6	−2·6
17	2	2415257	2415257·0	0·0
18	5	2415528	2415528·5	−0·5
19	+ 6	2415619	2415618·9	+0·1

TABLE IV.

Minima Dates.

Rotation No.	E.	Julian Day. J	Computed Min. J	O−C. d
1	−19	2413310	2413313·1	−3·1
2	19	2413311	2413313·1	−2·1
3	18	2413405	2413403·5	+1·5
4	15	2413676	2413674·9	+1·1
5	15	2413680	2413674·9	+5·1
6	14	2413765	2413765·4	−0·4
7	7	2414398	2413898·7	−0·7
8	3	2414755	2413760·6	−5·6
9	− 2	2414849	2414851·1	−2·1
10	+ 1	2415122	2415122·5	−0·5
11	2	2415214	2415212·9	+1·1
12	5	2415485	2415484·4	+0·6
13	+ 6	2415578	2415574·8	+3·2

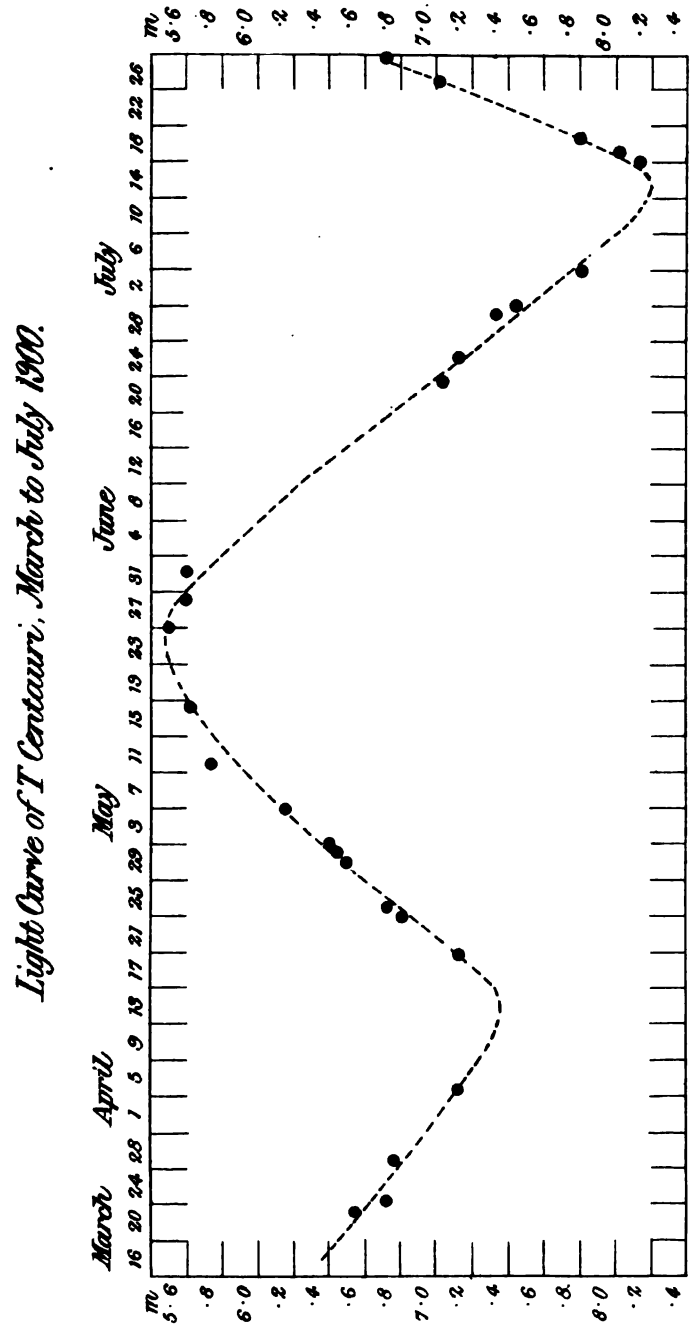
The average residual is :

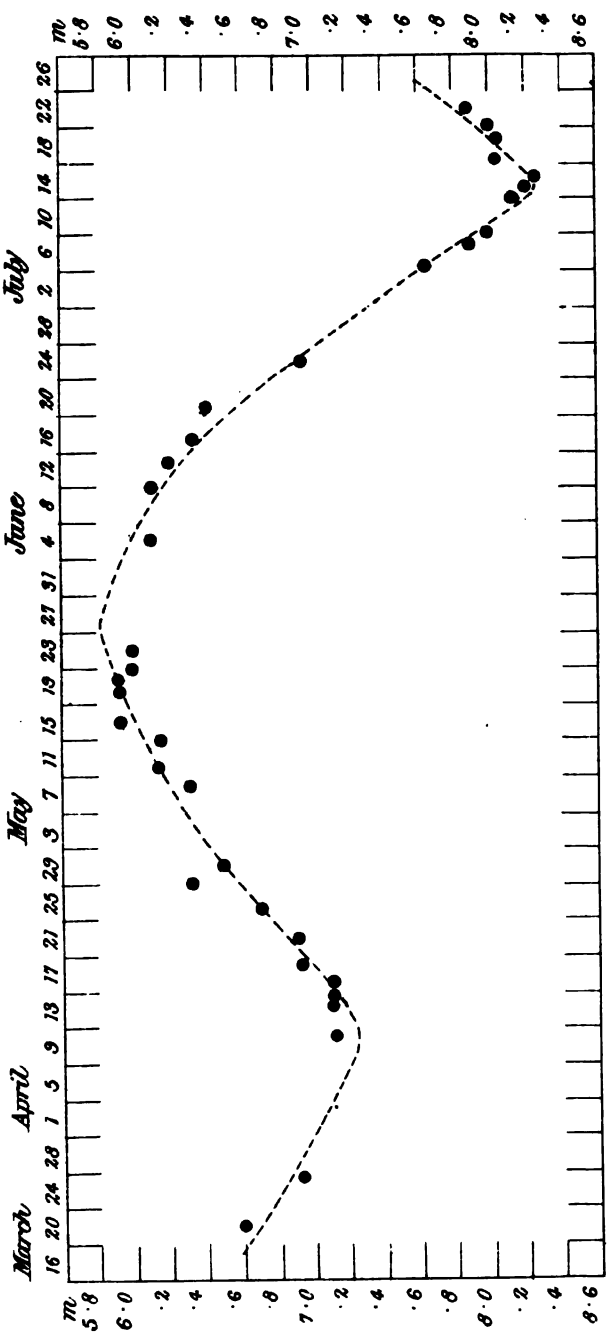
	d.
Maxima dates	2·5
Minima dates	2·1

That the latter value is the smaller is due to the fact that the minimum of this star is much more distinctly defined than the maximum phase.

The important element

$$M-m=44^{d}\cdot1$$


Light Curve of T Centauri, March to July 1900.
March
April
May
June
July
m
5·6
6·0
7·0
8·0



Light Curve of T Centauri, March to July 1901.

agrees very closely with that determined by Colonel Markwick, forty-three days (*Monthly Notices, R.A.S.*, vol. lviii., p. 514), and indicates that the duration of the ascending period of variation is not markedly unequal to the descending period.

This practical equality between ascending and descending portions of the light curve is a feature of not a few long-period stars.

Colonel Markwick finds a lower limit of $10^m{\cdot}0$ for the variation of *T Centauri*, but I think this is due to his underestimate by more than a whole magnitude of the brightness of two of the comparison stars used by him. The two stars are :

		h	m	s	°	′	
Z.C. xiii.^{h}	2039	13	34	0	33	1·3	(1875)
	2082	13	34	36	33	7·9	

The mean brightness of both stars is given in the Zone Catalogue as $8\frac{3}{4}$ magnitude. They have been regularly used at Lovedale as comparison stars for *T Centauri*, and I estimate them as between 8·6 and 8·8 magnitude. They are both distinctly seen in a 1-inch glass.

Colonel Markwick however considers them as 10·0 magnitude, a value which I am convinced is $1\frac{1}{2}$ magnitude too faint.

If allowance be made for this disparity in the reference standards it will be found that the range of magnitude obtained by Markwick confirms that determined at Lovedale.

In one of his papers on this variable Colonel Markwick pointed out that the range of variation was subject to considerable irregularity. This irregularity can be well exemplified by charting down two full cycles, one cycle in 1900 and the other in 1901.

These light curves are given in plates 1 and 2. The apparent similarity between the curves, indicating apparently alternative primary and secondary minima, is fortuitous. There is no regular succession of bright and faint minima, as is the case in some of the better known long period variables.

What has been stated or determined in the preceding part of this paper is deduced directly and solely from recent observations. In the case of *T Centauri* we have fortunately some old observations which I think may reasonably be used either to correct or supplement results obtained from more recent data.

These observations are :—

	Mag.	
1752 June 2	7·0	Lacaille
1846 June 6	8·0	Washington Obsns.
1849 Feb. 13	8·9	,,
March 23	8·0	,,
1862 April 17	6·0	Yarnall
1863 April 17	6·0	,,

		Mag.	
1870	Jan. 7	6·0	Yarnall.
	Jan. 17	6·0	,,
1872	May 4	7·5	Washington Obsns.
	May 14		
	May 27		
1873	June 17	7·0	Cordoba Obsns.
	June 30	7·5	,,
1874	July 2	6·8	,,
	July 3	7·5	,,
	July 4	7·3	,,
	July 11	7·0	,,
1875	June 16	7·0	,,

As an indication of the uncertainty which must belong to any determination based simply on meridian observations of magnitude, Colonel Markwick regards Lacaille's observation as taken near a maximum of the star. In my judgment the observation was taken near a minimum. In such uncertainty as this the observation must be set aside.

With regard to the early Washington observations we have more definite data to go upon. It is evident that a minimum took place on or about 1849 February 13. Yarnall's observations, also, clearly point to a maximum on or about 1862 April 17.

The Cordoba observations do not indicate a point of reference that we may accept with confidence. I think, however, that 1874 June 15 as the date of a maximum phase is not much in error.

In the *Astronomische Nachrichten*, No. 3269, Professor Pickering gives a valuable series of photographic magnitudes of *T Centauri*.

These indicate a minimum on 1893 July 27.

We have therefore the following four dates to which we may relate recent observations :—

		Julian Day.
1849 Feb. 13	Minimum	2396437
1862 April 17	Maximum	2401248
1874 June 15	,,	2405690
1893 July 27	Minimum	2412672

It is found that a period of $90^{d}\cdot30$ will better satisfy the earlier measures than the period $90^{d}\cdot47$ determined from recent observations. The correspondence with this shorter period is as follows :—

E.	Observed date.	Computed date.	O−C. d.
−206	2396437	2396430	+ 7
153	2401248	2401260	−12
104	2405690	2405685	+ 5
− 26	2412672	2412684	−12

If the larger value, $90^d{\cdot}47$, be related to the last observation the residual is only -7^d. It is evident, therefore, that the period of *T Centauri* is affected by some secular variation, the nature and amount of which we can only discover when a fuller series of observations has been secured.

The mean period of the star will probably be found to be not far from 90·3 days, with a range of from two to three days on either side of this mean period.

I would seek to acknowledge my great indebtedness to Sir David Gill and to Mr. R. T. A. Innes for their ever-ready willingness to make remoteness from a complete astronomical library less of a hindrance in investigations such as the preceding. They were good enough in the present instance to look up for me all the old records of *T Centauri*.

Lovedale: 1901 *October* 1.

On the Place of the Variable RU Herculis and Neighbouring Stars from Photographic Measures. By F. A. Bellamy, F.R.Met.Soc.

In No. 3384 of the *Astronomische Nachrichten* Dr. T. D. Anderson refers to a star of the ninth magnitude not given in B.D. He noted it as 9·1 magnitude in 1895 August; it was below the tenth magnitude on October 16, and became invisible later.

As there were several stars in the field of view of similar magnitudes, which rendered it difficult to identify the probable variable star with certainty, it seemed necessary that the position of it should be accurately determined, and this Dr. Hartwig did by measurement from two stars in the Cambridge and Berlin A.G. Catalogues with the heliometer; his results are included in an article on variable stars in *Astronomische Nachrichten*, 3553, and the positions given are

$$1900{\cdot}0 \quad \text{R.A. } 16^h\ 6^m\ 2^s{\cdot}76 \qquad +25^\circ\ 19'\ 54''{\cdot}7$$

and he adds a note to the effect that his observation was rendered difficult by the low altitude of the star and atmospheric conditions.

This star is in the region apportioned to this observatory for

the Astrographic Chart, and upon examination we find that it has been photographed on three plates.

		h m			
427	R.A.	16 4	+25°	exposed	1893 June 12
778		16 8	+26		1895 May 29
1406		16 8	+26		1899 May 26

Plate 1406 replaces plate 778, as the latter only showed 76 stars with 2 images and 11 stars with 3 images, the exposures being 6^m, 3^m, and 20^s. Plate 1406 has 188 and 80 stars.

It seems important, as pointed out in a previous paper on *Nova Persei*, that the positions of variables and neighbouring stars should be given accurately. The object of this paper is to give accurate places of the variable star *RU Herculis*, and of all the stars photographed within 20′ of it; therefore all stars probably to the eleventh magnitude. By means of these the positions of other intermediate and fainter stars can readily be determined when required for comparison.

The measures of plate 427 were made by Mr. H. A. Freeborn in 1897 July 23, and of plate 1406 by Miss E. F. Bellamy 1900 September 11–14. The constants a, b, c, d, e, f were determined from a comparison of the computed ξ' and η' (1900·0) for stars in the Cambridge and Berlin A.G. Catalogues, with the measures corresponding to the same stars; they are for

	a	b	c	d	e	f
Plate 427	+·00762	+·00164	−·3719	−·00190	+·00762	−·0918
1406	−·00026	+·00447	−·2910	−·00436	−·00045	−·1314

The application of these constants in the usual way gives the ξ' and η' in Table I., but these coordinates need only be given for plate 1406; the right ascensions and declinations (1900·0) were obtained for both plates, and the positions are the means of the two. The eighth and ninth columns contain the differences between the two plates.

The magnitudes in the third column are estimations, to the nearest third or half magnitude, made by myself in November this year.

TABLE I.

Ref. No.	Camb. A.G.C.	Oxford Mag.	ξ' 1900·0 Plate 1406.	η' 1900·0.	Deduced R.A. 1900·0.	Deduced N. Dec. 1900·0.	Difference 1406-427 in R.A.	Difference 1406-427 in Dec.
					h m s	° ′ ″	s	″
1	7492	9·5	1·3834	2·9930	16 3 43·30	25 9 44·6	+0·13	−0·7
2		10·0	2 6205	1·9904	4 10·78	4 47·0	+ ·12	−1·3
3		9·7	2·7987	4·5099	4 14·32	17 23·5	+ ·11	−2·2
4		11·0	2·8255	6·4584	4 14·66	27 6·8	...	...
5		11·0	2 9175	8·9776	4 16·30	39 42·6	...	....

Ref. No.	Camb. A.G.C.	Oxford Mag.	ξ' 1900·0 Plate 1406.	η' 1900·0.	Deduced R.A. 1900·0.	Deduced N. Dec. 1900·0.	Difference 1406–427 in R.A.	Difference 1406–427 in Dec.
					h m s	° ′ ″	s	″
6		10·0	2·9761	5·4301	16 4 18·17	25 21 59·1	+0·06	−0·8
7		10·5	3·5413	2·9689	4 30·94	9 41·8	+ ·16	−0·2
8		10·0	3·7853	8·;807	4 35·57	38 45·2	+ ·01	+0·2
9		9·7	3·7778	6·5631	4 35·71	27 40·4	+ ·04	−0·6
10	7496	8·5	3·9927	3·3620	4 40·90	11 40·5	+ ·11	−0·1
11		9·7	4·7037	6·5747	4 56·36	27 45·4	+ ·01	−0·1
12		10·3	4·7900	6·8087	4 58·11	28 56·0	·00	−0·7
13		10 7	6·9414	4·3294	5 45·93	16 35·8	+ ·15	−1·3
14		10·0	7·3974	3·1658	5 56·15	10 47·0	+ ·08	−0·5
15		11·0	7·5099	6·2204	5 58·41	26 3·1	...	...
16	Variable		7·7077	4·9903	6 2·89	19 54·3	...	...
17		10·3	7 8055	3·3878	6 5·15	11 53·8	+ ·06	0·0
18		11·0	8·1264	2·4336	6 12 24	7 8·3	+ ·20	−0 9
19		11·0	8 5363	5·6330	6 21·18	23 7·9	...	...
20		9·5	8·6046	7·2410	6 22·58	31 10·9	− ·01	−1·2
21		10·0	8·7604	6·4043	6 26·09	26 59·6	·00	−0·2
22		10 7	8·8989	2·2604	6 29·35	6 16·6	+ ·15	+0·3
23		9·5	9·2947	7·5711	6 37·88	32 50·8	− ·04	−1·6
24		11·5	9·6254	5·2190	6 45·31	21 4·7	...	...
25		11·5	9·8601	1·9414	6 50·66	4 41·7	...	...
26		10·0	10·2265	6·6907	6 58·54	28 26·5	+ ·02	−0·3
27		11·3	10·3339	8·3776	7 0·86	36 52·6	...	...
28		9·5	10·7712	6·9873	7 10·62	29 56·1	− ·02	−0·8
29	7525	8·7	10·80c4	3·7127	7 11·38	13 33·9	− ·05	+0·4
30	7528	8·5	10·9892	9·1522	7 15·38	40 46·2	− ·04	−1·9
31	7533	8·7	12·1575	6 9210	16 7 41·32	25 29 36·3	·00	0·0

Nos. 4, 5, 15, 19, 24, 25, 27 are not visible on plate 427. Though *RU Herculis* is visible on plates 427 and 778, the images are so faint that satisfactory measures cannot be made; when the scale is placed over them they become invisible.

With regard to the differences (especially in R.A.) it should be mentioned that the constants for these two plates (427 and 1406) were derived from stars in the Catalogue of the Ast. Gesellschaft, observed at Cambridge and Berlin. For plate 1406 all the stars are from the Cambridge, whilst for plate 427 five of

the twenty-five stars used are from the Berlin B. Catalogue, all these being in the southern half of the plate. The question arises whether there is any systematic difference between the R.A.'s of Cambridge and Berlin B. Catalogues.

In the introduction to the Greenwich 1890·0 Catalogue, p. 47, comparisons are given Greenwich—Cambridge and Greenwich—Berlin B., and the systematic differences in R.A. are $-0^s{\cdot}04$ (198 stars) and $-0^s{\cdot}03$ (282 stars), whence C—B is $+0^s{\cdot}01$. But this comparison depends on the brighter stars only, and for our present purpose is illusory; for, the majority of stars in Cambridge and Berlin B. Catalogues are of the 8th to the 9th magnitude, and even fainter, and the Cambridge observations are affected by a very pronounced magnitude equation, as pointed out by Mr. A. R. Hinks (*Monthly Notices*, lvii., p. 473), using 671 stars, and by Professor Turner (*Monthly Notices*, lx., p. 3), using 5,384 stars. In fact, while the R.A.'s of the mean bright star (probably about the $5\frac{1}{2}$ or 6th magnitude) of the Cambridge and Berlin are the same, those of the mean 8th and 9th magnitude star differ by $0^s{\cdot}07$ at least.

If, then, the places from Cambridge and Berlin are taken just as they stand, the lower and southern half of the plate, depending chiefly on Berlin stars, will be displaced in R.A. with reference to the northern half of the plate; and this will alter the orientation (constant b) deduced from the x coordinates. Assuming the above difference of $0^s{\cdot}07$, the effect is to increase b by $+{\cdot}00025$, and there is a consequent correction of $-{\cdot}0053$ to c. A systematic difference has been noticed in declination by Mr. Hinks, the amount being $0''{\cdot}5$, which will similarly alter the scale value (constant e) deduced from the y coordinate.

In the particular case of plate 427 these quantities are probably excessive, for there are 5 Berlin stars in the lower half, but the total number is 8. Nevertheless they are quite inadequate to account for the systematic difference in R.A. as appears from the subjoined Table II., in which the differences in Table I. are compared with those due to the above alterations in b and c.

The main cause of the discordance between the two plates must accordingly be sought for elsewhere—probably in the accidental errors of the reference stars (including proper motions from the dates of meridian observations to 1900·0, and for the six years between the two plates)—and though these will ultimately be fully discussed, for the present it will serve the main purpose of this paper to give the mean of the results as they stand, as has been done in Table I.

TABLE II.

Plate 1406–427.

Ref. No.	Difference as in Table I.	Correction for Magnitude Equation.	Difference Corrected.
	s	s	s
1	+0·13	−0·03	+0·10
2	+ ·12	− ·03	+ ·09

Ref. No.	Difference as in Table I. s	Correction for Magnitude Equation. s	Difference Corrected. s
3	+0·11	−0·02	+0·09
6	+ ·06	− ·01	+ ·05
7	+ ·16	− ·03	+ ·13
8	+ ·01	+ ·01	+ ·02
9	+ ·04	− ·01	+ ·03
10	+ ·11	− ·03	+ ·08
11	+ ·01	− ·01	·00
12	·00	− ·01	− ·01
13	+ ·15	− ·02	+ ·13
14	+ ·08	− ·03	+ ·05
17	+ ·06	− ·03	+ ·03
18	+ ·20	− ·03	+ ·17
20	− ·01	·00	− ·01
21	·00	− ·01	− ·01
22	+ ·15	− ·03	+ ·12
23	− ·04	·00	− ·04
26	+ ·02	·00	+ ·02
28	− ·02	·00	− ·02
29	− ·05	− ·02	− ·07
30	− ·04	+ ·01	− ·03
31	·00	·00	·00

The plates afford some information as to the magnitude of the variable. On plate 427 ($16^h\ 4^m + 25°$ 1893 June 12) it is at the limit of visibility; in fact, it had been omitted in the original measures of the plate, though stars certainly as faint as 10·5 mag. had been measured, and was only detected when examining it for this paper by first computing its coordinates, and so knowing exactly where to look for it.

The star is visible on plate 778 ($16^h\ 8^m + 26°$ 1895 May 29), but again was only found by previously ascertaining its exact position. The plate had been rejected as having an insufficient number of stars; there were only 11 stars shown by the 20^s exposure, whereas Argelander gives 57 in the same region. It can be inferred that quite 1·5 magnitudes were lost on this plate, and so the magnitude of *RU Herculis* would be about 9·5. It was in 1895 August that Dr. Anderson first noticed that the star was missing in the B.D., and he then estimated it to be 9·1.

When the third plate (1406) was taken, 1899 May 26, the star was very near its maximum, and was undoubtedly as bright or brighter than Camb. 7533 (B.D. + 25°, 3046), magnitude 9·0.

If the star is red in appearance this will be equivalent to increasing the mags. given from the plates by at least several tenths

Dr. Hartwig gives the period as 473* days. According to Mr. J. A. Parkhurst, the star is equal to the fourteenth magnitude at its minimum.†

Further Observations of the New Star in Perseus made at the Radcliffe Observatory, Oxford.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

This paper contains the results of observations upon the brightness and colour of the new star in *Perseus* made at the Radcliffe Observatory since the date of the last meeting of the Society, and is in continuation of the Notes on the same subject already communicated to the Society, and published in the *Monthly Notices* for March, April, May, and June.

The periodical fluctuations in the brightness of the *Nova* which had been observed up to the end of the first week in June appeared to die out about the middle of that month. The last observed maximum ($4^m \cdot 57$) was on June 8. The next estimation of magnitude was $5^m \cdot 80$ on June 17, and since that date the observations show a gradual diminution of brightness at the rate of about $0^m \cdot 01$ per diem, the magnitude on November 1 being 7·1. If the magnitudes be plotted as ordinates with the dates as abscissæ, a straight line drawn through them will lie within $0^m \cdot 2$ of all observations, and the discrepancies show no trace of periodicity. Small changes of brightness have occasionally been suspected by the observers in the course of a night's observations.

During the months of June and July the star was observed under unfavourable conditions at a small altitude above the northern horizon. In July the image of the *Nova* was frequently noted as being "dull," and "larger" than the other stars, but since then it has generally appeared sharp and stellar.

On August 22 the image of the *Nova* was carefully examined to test whether any trace could be found visually of the aureole which MM. Antoniadi and Flammarion had seen surrounding the photographic image. No indication of such an aureole could be discovered (see Observers' Notes for that date).

A marked change has also taken place in the colour of the star. The redness previously conspicuous at minimum has gradually disappeared, and the star is now for the most part colourless. On June 17 it was described as very red. From August 8 to August 24 it appeared pale yellow with occasionally a red fringe which did not show in the other star images. From August 27 to November 1 it is generally noted as colourless, with,

* *Vierteljahrsschrift der Astron. Gesell.*, Jahr. 34, p. 315.
† *Astrophysical Journal*, vol. xiv. p. 172.

on one or two occasions, an indication of blue. Since July 3 the star *Arg. Z.* +43°, 730 (No. 58 in Table I.) has appeared considerably redder than the *Nova*.

The stars *Arg. Z.* +44°, 734 and *Arg. Z.* +43°, 730 (Nos. 54 and 58 in Table I.) have been frequently used as comparison stars. If the magnitudes given in the Harvard Photometry, Harvard Photometric Revis., and Harvard Photometric D.M., be accepted, it is found that the magnitude of the *Nova* resulting from a comparison with these stars differs systematically from that deduced by comparison with the other stars. Comparing the magnitudes of these two stars with a number of others the resulting magnitudes on the Harvard scale were found to be 6·23 and 6·57 respectively. The magnitudes given for No. 54 in the H.P., H.P. Revis., and H.P. D.M. are 6·04, 6·32, and 6·45. The magnitude given for No. 58 in the H.P. D.M. is 6·91. It will be seen that the Radcliffe estimation of No. 54 on the Harvard scale agrees more closely with the mean of the three photometric results (6·27) than with the first of them, the magnitude hitherto adopted.

These revised magnitudes have been used in Table I. and throughout the comparisons given in this paper.

The following instruments were employed as indicated in the fourth column of Table II. :—

	Instruments Used.	
Barclay	10-inch equatorial	Power 90
	2·7-inch finder	„ 13
Heliometer	7·5-inch	„ 45
	1·8-inch finder	„ 19
Ramsden	2·2-inch	„ 40
Naked eye.		

TABLE I.

List of Stars used for Comparison with Nova Persei.

Ref. No.	Name of Star.	Harvard Photom. Mag.	Ref. No.	Name of Star.	Harvard Photom. Mag.
50	*l* Persei	4·84	61	Arg. Z. +41°, 631	6·00†
51	31 Persei	4·99	62	Arg. Z. +41, 638	6·16†
52	30 Persei	5·37	63	Arg. Z. +42, 736	7·00§
53	36 Persei	5·40	64	Arg. Z. +43, 729	7·25§
54	Arg. Z. +44°, 734	6·23*	65	Arg. Z. +43, 732	7·25†
55	Arg. Z. +44, 648	6·47‡	66	Arg. Z. +47, 847	5·52†
56	Arg. Z. +43, 818	5·97	67	Arg. Z. +44, 714	7·37†
58	Arg. Z. +43, 730	6·57*	68	Arg. Z. +47, 844	6·04†
59	Arg. Z. +42, 795	6·30†	69	Arg. Z. +47, 846	6·77†
60	Arg. Z. +44, 656	7·60§	70	Arg Z. +44, 732	7·32†

* Radcliffe estimations on Harvard scale. † Harvard Photom. D.M.
‡ Harvard Photom. Revision. § Adopted provisionally.

TABLE II.

Means of Estimations of Magnitude of Nova Persei.

1901.	G.M.T. h	m	Observer.	Aperture of Telescope. inch	Reference Stars.	Mean Mag.	Adopted Mag. for the night.
June 17	10	40	R.	7·5	52, 56	5·80	5 80
18	10	50	R.	7·5	52, 54, 56	5·99	5·99
July 1	11	5	R.	7·5	52	5·90	5·90
3	11	0	R.	7·5	52, 54	6·00	6·00
8	11	30	R.	7·5	52	5·97	5·97
9	11	45	R.	1·8	52 56, 54, 58	5·91	6 07
	11	45	R.	7·5	52, 54, 58	6·22	
15	10	30	R.	1·8	54, 52, 56, 58	6·02	6·11
	10	30	R.	7·5	54, 52, 58	6·16	
	11	40	A. A. R.	7·5	58, 54	6·15	
	11	40	A. A. R.	1·8	58, 54	6·15	
16	10	15	R.	1·8	52, 56, 54	5·86	5 86
17	11	0	R.	1 8	52, 56, 54, 58	6 22	6 22
18	11	0	R.	1 8	56, 52, 54	5·99	5·92
	11	20	C.	1·8	56, 52, 54, 58	5 85	
19	10	30	R.	1·8	52, 56, 54	5·92	5·92
	11	30	R.	2·7	52, 56, 54	5·92	
20	10	0	R.	1 8	52, 54, 56	5·92	5·92
22	10	30	R.	1·8	56, 52, 54	5·97	5·97
23	10	30	R.	1·8	52, 54	5 93	5·93
24	11	15	R.	1 8	52, 54, 56	6·09	6·09
Aug. 8	11	45	C.	2·7	52, 56, 55, 54	6·34	6·34
10	10	30	C.	2·7	54, 52, 55, 56	6·45	6·45
15	9	30	C.	2·7	55, 54, 58, 56	6·50	6·50

1901.	G.M.T. h	m	Observer.	Aperture of Telescope. inch	Reference Stars.	Mean Mag.	Adopted Mag. for the night.
Aug. 17	10	0	C.	2·7	56, 55, 54, 67	6·51	6·51
20	10	50	R.	Naked eye	54, 59	6·46	6·46
22	9	30	W.	2·7	54	6·13	6·22
	9	30	W.	10·0	54, 53	6·02	
	10	45	R.	Naked eye	54, 59	6·46	
24	10	20	R.	10·0	56, 54	6·30	6·30
27	11	53	R.	2·7	56, 54, 58	6·42	6·42
28	8	45	R.	1·8	58, 54	6·25	6·25
Sept. 3	7	45	R.	7·5	54, 56, 70–54, 58	6·65	6·54
	9	0	R.	Naked eye	54, 59	< 6·30	
	10	45	R.	2·7	56, 58, 54	6·42	
4	7	43	R.	7·5	54, 70	6·77	6·67
	7	43	R.	1·8	56, 70, 54, 58	6·77	
	8	45	R.	1·8	56, 54, 70, 58	6·57	
	9	30	R.	Naked eye	54, 59	6·57	
5	9	7	W.	2·7	58, 62, 61, 55, 54, 68, 69	6·46	6·45
	9	7	W.	10·0	58, 62, 61, 55, 54, 68, 69	6·44	
	10	45	R.	Naked eye	54 59	< 6·30	
7	9	25	R.	2·7	65, 54, 58	6·58	6·58
9	9	40	W.	10·0	58, 64, 65	6·77	6·65
	9	40	W.	2·7	58, 62, 61, 64, 55, 69, 68, 66	6·72	
	10	15	R.	Naked eye	54, 59	6·62	
	11	5	W.	2·2	58, 54, 65	6·42	
10	9	35	R.	2·7	56, 54, 58, 65, 64	6·72	6·72
11	7	40	R.	7·5	70, 54, 56	6·74	6·54
	9	40	W.	2·7	58, 54, 62, 63, 56, 69	6·52	
	9	40	W.	10·0	58, 54, 62, 63	6·43	
14	8	20	W.	2·7	54, 58	6·80	6·65
	8	30	R.	7·5	54, 70, 56	6·74	
	9	30	R.	1·8	54, 56, 58, 65	6·46	

1901.	G.M.T. h	m	Observer.	Aperture of Telescope. inch	Reference Stars.	Mean Mag.	Adopted Mag. for the night.
Sept. 18	7	50	R.	7·5	58, 54, 70, 56	6·87	6·79
	8	55	R.	1·8	65, 64, 54, 56, 58	6·71	
21	9	30	C.	2·7	54, 65, 56	6·73	6·73
25	8	5	R.	2·7	58, 54, 65, 64, 56, 70, 67	6·72	6·72
26	8	30	C.	2·7	54, 65, 56, 58	6·75	6·74
	8	53	W.	2·7	58, 65, 54, 62, 63, 55, 60	6·73	
28	9	0	C.	2·7	65, 54, 58, 64, 56, 55	6·81	6·81
Oct. 4	9	15	R.	2·7	58, 54, 70, 67, 65, 64, 56	6·84	6·84
5	9	8	C.	2·7	65, 54, 64	6·74	6·74
9	7	45	R.	2·7	56, 54, 70, 67, 58, 65, 64	6·84	6·84
18	6	50	R.	2·7	65, 64, 58, 54, 70, 67	6·94	6·94
19	8	15	C.	2·7	54, 65, 58, 67, 56	6·93	6·93
21	7	15	R.	10·0	58, 54, 70, 56	6·79	6·79
22	8	30	C.	2·7	65, 54, 58, 67	6·86	6·86
24	8	38	C.	2·7	65, 64, 54, 67, 70, 58	7·16	7·16
25	6	45	R.	2·7	65, 64, 70, 67	7·32	7·15
	6	45	R.	10·0	65, 64, 70	7·39	
	9	0	W.	1·8	58, 54	6·70	
	9	30	R.	1·8	65, 64, 67, 70, 58	7·06	
30	11	0	R.	2·7	65, 64, 58, 67, 70	7·03	7·03
31	8	38	C.	2·7	65, 64, 58, 67, 70	7·20	7·20
Nov. 1	7	0	R.	2·7	65, 64, 58	7·12	7·12

Observers' Notes on the Estimations of Magnitude.

1901.
June 17. Nova low, but sky very clear.
July 1. Sky very cloudy.
3. Clouds passing, but estimations fairly reliable.
8. Images varying through shifting fog-banks.
9, 15, 17, 19. In the 7·5-inch the Nova is fainter than No. 58, whilst in the 1·8-inch finder it is much brighter. The image of the Nova is, in the 7·5 inch, duller than that of No. 58, but it is larger. (R.)

1901.
July 15. No. 58 is brighter than No. 54 in the 7·5-inch, but the two stars are equal in the 1·8-inch. In both telescopes the Nova is brighter than No. 54. (A.A.R.)
18. Comparison with No. 58 difficult owing to close proximity of other stars. Sky hazy. (C.)
19. Image of Nova in the 10-inch is duller than that of No. 58. Sky hazy in places.
23. Sky nearly overcast; observed in breaks.
24. Difficult observations; cloud occasionally passing.
Aug. 10. Sky very clear and definition good.
15. Haze and thin cloud prevalent. Definition not satisfactory.
17. Sky very clear in Perseus. Definition good.
20. Nova just visible to the naked eye, fainter than Nos. 54 and 59. Sky brilliantly clear.
22. To test whether Flammarion's and Antoniadi's photographic aureole could be detected visually, examined Nova with Barclay Equatorial. No difference of image as compared with other stars could be seen with "finder" or 10-inch telescope, using powers 90 or 250. With 250 all images were diffused to-night. (W.) Nova visible to the naked eye by glimpses only. (R.)
24. In the 10-inch No. 54 is distinctly brighter than Nova, but in the 2·7-inch "finder" it is fainter. Sky foggy.
27. Sky clear, but moonlight strong.
Sept. 3. With the 7·5-inch images sharp and good; objects low, observed in twilight. At times the image of the Nova in the 2·7-inch seemed larger than that of No. 54, but its light was duller. With the naked eye Nos. 54 and 59 were seen with but little difficulty, but the Nova was not visible.
4. Observations difficult with the 1·8-inch. The brightness of the Nova seemed to fluctuate in short intervals to the extent of about 0·2 magnitude. With the naked eye the following sequence of magnitude was recorded:—Nos. 50; 53 and 52 nearly equal; 54 and 59 nearly equal; Nova, by glimpses, but suspected only.
5. To the naked eye Nos. 54 and 59 just visible. Nova invisible. (R.)
7. Images varying; clouds passing. Observations difficult.
9. Sky very clear. (W.) No. 54 is easily visible to the naked eye, brighter than No. 59, which is also picked up with but little difficulty. Both stars are distinctly brighter than Nova, which shows up in glimpses only. (R.)
11. Sky hazy. (R.) Thin cloudlets passing at times and occasional large tracts of cloud. Very good images generally. (W.)
14. A hurried comparison. (W.)
18. Image of the Nova sharp and stellar with the 7·5-inch. Some haze passing during observations with the 1·8-inch.
21. Clouds passing. Object-glasses of 10-inch and 2·7-inch "finder" became quickly covered with moisture. Very damp atmosphere.
25. In the 2·7-inch Nos. 54 and 58 are equal in magnitude. In the 10-inch No. 67 is double, but in the 2·7-inch single.
Oct. 5. Hurried estimations owing to prevalence of cloud.
21. Through passing cloud and mist; observations difficult.
22. Haze and thick low fog prevalent.
25. With the 2·7-inch No. 65 is slightly fainter than No. 64; and Nova is considerably fainter than No. 58. With the 10-inch, power 90, No. 65 is fainter than No. 64. Sky hazy in places and moonlight strong. With the 1·8-inch No. 65 is slightly brighter than No. 64. Sky clearer than at $6^h\ 45^m$ G.M.T.; but some haze still prevalent, with moonlight. (R.)

Observers' Remarks on Colour of Nova and Comparison Stars.

1901.

June 17. Nova very red.

July 1. No marked colour in Nova.
3. Nova is red, but not nearly so red as No. 58.
9. With the 7·5-inch Nova is orange, and No. 58 orange-red.
15. Nova orange-red, but less red than No. 58, in the 7·5-inch. (R.) No. 58 more red than Nova in both telescopes. (A.A.R.)
16, 17. Nova orange; No. 58 orange-red.
18. Nova orange and No. 58 red in the 7·5-inch. (R.) Nova not so red as No. 58 in the 7·5-inch. (C.)
19. In both 7·5-inch and 10-inch Nova orange and No. 58 orange-red.
22. In the 7·5-inch Nova orange-red; No. 58 red.
24. In the 7·5-inch Nova less red than No 58.

Aug. 8. In the 10-inch Nova pale yellow, much less coloured than No. 58.
10. In the 10-inch Nova much less coloured than No. 58, which is deep orange. At times suspected a reddish fringe to the Nova.
17. In the 10-inch Nova is pale yellow; in strong contrast to No. 58, which is deep orange.
24. Nova orange, not so deep as No. 58. Sky foggy. Moon ruddy, or deep orange.
27. With the 10-inch, power 90: Nova white, with small red wings, and No. 58 orange. Marked contrast in colours with powers 180 and 200. Nova nearly colourless, and No. 58 red-orange. Definition not good with the latter powers to-night.
28. In the 7·5-inch the Nova is colourless and No. 58 orange.

Sept. 3. No colour to Nova in the 7·5-inch, except at intervals, when a merest tinge of red was suspected; No. 70 is reddish; No. 58 rich orange-red.
4. In the 7·5-inch No. 58 orange-red, Nova colourless. In the 1·8-inch Nos. 70 and 58 both orange-red.
5. In the 10-inch No. 62 is yellow-red, No. 61 bluish-white, and No. 55 markedly red-yellow. (W.)
7. No. 58 orange-red in the 2·7-inch.
9. No. 58 is red in the 2·7-inch and No. 55 is a pronounced red. In the 10-inch with power 90 no marked colour to Nova. With power 100 Nova is reddish; also reddish with power 200, but not so marked. No. 58 is strongly red. (W.)
10. In the 10-inch No. 58 is orange-red and Nova colourless.
11. No colour to Nova in 10-inch or 2·7-inch. (W.)
14. Nova colourless in the 7·5-inch and No. 70 orange-red. (R.) In the 10-inch, power 90, the image of the Nova was, at 10h G.M.T., a bluish-white disc with a narrow reddish fringe. (W.)
18. No. 58 orange-red in the 7·5-inch.
25. In the 10-inch Nova is bluish-white with very small red wings. No. 58 is red-orange. No. 67 is double; the brighter star white, the fainter orange.
26. With the 10-inch and power 90 could not detect any coloured fringe to Nova. (C.) No. 58 yellow in the 2·7-inch. With 10-inch and power 90 Nova is very light yellow, with a faint tinge of red on the border of the image. (W.)
28. In the 10-inch, power 90, Nova is a very pale yellow, with a faint red border showing at times.

Oct. 4. In the 10-inch, power 90, Nova bluish-white and No. 58 reddish-yellow.
9. In the 10-inch, power 90, Nova white and No. 58 orange.
18. In the 10-inch, power 90, Nova white; No. 58 orange; No. 67 is double, the fainter star reddish.
21. Nos. 58 and 70 are orange-red in the 10-inch.

1901.
Oct. 24. Nova white and No. 58 deep orange in the 10-inch.
25. No. 64 is light orange and No. 70 orange-red in the 10-inch, power 90. (R.)
31. In the 10-inch, power 90, Nova is white and is ½rd mag. fainter than No. 58, which is deep orange.

The observers were: Dr. Rambaut, indicated by A.A.R.
Mr. Wickham, „ W.
Mr. Robinson, „ R.
Mr. McClellan, „ C.

Radcliffe Observatory, Oxford:
1901 *November* 7.

Additional Note on the Green Flash. By W. H. Pickering.

(*Communicated by the Secretaries.*)

During a recent sea trip I made some further observations upon the green flash at sunset. I was some five or six miles off the Massachusetts coast, and my assistant, Mr. E. R. Cram, and I were watching the Sun set over the land, which was very low at this place. The horizon was fairly clear, and just as the Sun was on the point of disappearing the last ray turned to both of us a bright green. The effect was not so marked, however, as in the sunset I had previously witnessed off the Cuban coast. The next morning Mr. Cram saw the Sun rise out of the ocean, but no unusual colour was observed.

The effect is so marked at sunset that it is singular that it should not have been more generally noticed heretofore. The explanation it seems to me, however, is simple. The effect, I presume, is subjective, and merely a case of complementary colours, like the well-known experiment of gazing fixedly at a red wafer on a white background, then looking away, and seeing a green one in its place. The fact that my assistant could not see it at sunrise, although entirely prepared to do so, confirms this view.

Harvard Observatory:
1901 *October* 8.

Ephemeris for Physical Observations of the Moon for 1902.

By A. C. D. Crommelin.

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration: Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.	C.
1902.	°	°	°	°	°	°	°
Jan. 1	178·16	+1·33	+5·41	+3·03	6·20	299·3	24·28
2	190·32	1·34	+4·18	+1·73	4·52	292·5	22·83
3	202·49	1·35	+2·80	+0·38	2·83	277·7	20·39
4	214·66	1·36	+1·36	−0·98	1·68	234·2	17·06
5	226·84	1·37	−0·06	−2·30	2·30	178·5	12·93
6	239·02	1·38	−1·38	−3·53	3·79	158·6	8·16
7	251·20	1·39	−2·55	−4·61	5·27	151·1	2·95
8	263·39	1·40	−3·53	−5·50	6·54	147·3	357·57
9	275·58	1·41	−4·29	−6·14	7·49	145·1	352·26
10	287·77	1·42	−4·84	−6·50	8·11	143·3	347·33
11	299·96	1·43	−5·18	−6·54	8·35	141·6	343·00
12	312·14	1·44	−5·33	−6·24	8·21	139·5	339·49
13	324·32	1·45	−5·31	−5·61	7·72	136·6	336·95
14	336·50	1·46	−5·11	−4·66	6·92	132·4	335·54
15	348·67	1·47	−4·74	−3·44	5·86	126·0	335·39
16	0·83	1·48	−4·19	−2·01	4·65	115·6	336·59
17	12·99	1·48	−3·43	−0·43	3·46	97·1	339·20
18	25·13	1·49	−2·47	+1·19	2·74	64·3	343·16
19	37·27	1·50	−1·30	+2·76	3·05	25·2	348·34
20	49·41	1·51	+0·04	+4·17	4·17	359·4	354·38
21	61·54	1·52	+1·46	+5·31	5·51	344·6	0·82
22	73·66	1·52	+2·87	+6·09	6·73	334·8	7·11
23	85·79	1·53	+4·15	+6·48	7·69	327·4	12·79
24	97·91	1·53	+5·17	+6·47	8·28	321·4	17·51
25	110·04	1·53	+5·82	+6·07	8·41	316·2	21·09
26	122·18	1·53	+6·06	+5·34	8·08	311·4	23·44
27	134·31	1·53	+5·88	+4·35	7·31	306·5	24·58
28	146·46	1·53	+5·28	+3·17	6·16	301·0	24·56
29	158·61	1·53	+4·34	+1·87	4·73	293·3	23·42
30	170·77	1·52	+3·15	+0·52	3·19	279·4	21·28
31	182·93	1·52	+1·80	−0·84	1·99	245·0	18·20
Feb. 1	195·10	1·52	+0·38	−2·16	2·19	190·0	14·29
2	207·27	1·51	−1·00	−3·39	3·53	163·6	9·72
3	219·45	1·51	−2·26	−4·48	5·02	153·2	4·65
4	231·63	+1·50	−3·22	−5·39	6·28	149·1	359·30

Greenwich Midnight.	Selenographical Colong.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.	C.
1902.	°	°	°	°	°	°	°
Feb. 5	243·82	+1·50	−4·14	−6·06	7·34	145·7	353·94
6	256·01	1·49	−4·68	−6·45	7·97	144·0	348·82
7	268·20	1·49	−4·94	−6·53	8·19	142·9	344·22
8	280·40	1·48	−4·93	−6·26	7·97	141·8	340·38
9	292·60	1·48	−4·69	−5·65	7·34	140·3	337·49
10	304·79	1·47	−4·27	−4·71	6·36	137·8	335·75
11	316·98	1·47	−3·72	−3·49	5·10	133·2	335·29
12	329·16	1·47	−3·06	−2·06	3·69	124·0	336·21
13	341·34	1·46	−2·33	−0·48	2·38	101·6	338·51
14	353·52	1·46	−1·53	+1·13	1·90	53·6	342·16
15	5·69	1·45	−0·65	+2·68	2·76	13·6	346·99
16	17·85	1·45	+0·29	+4·07	4·08	355·9	352·70
17	30·00	1·44	+1·28	+5·21	5·36	346·2	358·80
18	42·15	1·43	+2·27	+6·03	6·44	339·4	5·11
19	54·29	1·42	+3·22	+6·48	7·23	333·6	10·89
20	66·43	1·41	+4·05	+6·54	7·69	328·2	15·88
21	78·56	1·40	+4·67	+6·21	7·78	323·1	19·86
22	90·70	1·38	+5·01	+5·55	7·48	317·9	22·68
23	102·84	1·37	+5·03	+4·59	6·81	312·1	24·21
24	114·98	1·35	+4·71	+3·42	5·82	306·0	24·72
25	127·13	1·34	+4·04	+2·11	4·56	297·6	23·97
26	139·29	1·32	+3·09	+0·72	3·17	283·1	22·14
27	151·44	1·30	+1·91	−0·67	2·02	250·7	19·34
28	163·61	1·28	+0·59	−2·02	2·10	196·3	15·69
Mar. 1	175·78	1·27	−0·80	−3·28	3·38	166·3	11·31
2	187 95	1·25	−2·15	−4·40	4·90	154·0	6·40
3	200·14	1·23	−3·38	−5·34	6·32	147·7	1·14
4	212·32	1·21	−4·40	−6·06	7·49	144·0	355·82
5	224·51	1·20	−5·14	−6·51	8·30	141·7	350·63
6	236·71	1·18	−5·56	−6·65	8·67	140·1	345 83
7	248·91	1·16	−5·63	−6·46	8·57	138·9	341·66
8	261·12	1·14	−5·36	−5·91	7 98	137·8	338 38
9	273·33	1·13	−4·78	−5·01	6·93	136·3	336·19
10	285·54	1·11	−3·96	−3·79	5·48	133·7	335·28
11	297·75	1·10	−2·98	−2·33	3·78	128·0	335·78
12	309·96	1·08	−1·90	−0·70	2·03	110·2	337 76
13	322·16	1·07	−0·78	+0·97	1·25	38 8	341·16
14	334·36	+1·05	+0·31	+2·58	2·60	353·1	345·82

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.	C.
1902.	°	°	°	°	°	°	°
Mar. 15	346·55	+1·03	+1·36	+4·03	4·25	341·4	351·41
16	358·73	1·01	+2·31	+5·21	5·70	336·1	357·52
17	10·91	0·99	+3·16	+6·08	6·85	332·5	3·69
18	23·08	0·97	+3·87	+6 57	7·63	329·5	9·51
19	35·24	0·95	+4·44	+6·69	8·03	326·4	14·63
20	47·40	0·93	+4·82	+6·43	8·04	323·1	18·82
21	59·56	0·90	+4·98	+5·82	7·66	319·4	21·95
22	71·71	0·88	+4·90	+4·91	6·93	315·1	23 92
23	83·87	0·85	+4·57	+3·77	5·92	309·5	24·73
24	96·03	0·83	+3·97	+2·46	4·67	301·8	24·37
25	108·19	0·80	+3·13	+1·06	3·30	288·7	22·89
26	120·35	0·77	+2·08	−0·38	2·11	259 6	20·39
27	132·52	0·75	+0·86	−1·77	1·97	205·9	16·97
28	144·69	0·72	−0·48	−3·08	3·12	171·1	12·80
29	156 87	0·69	−1·85	−4·26	4·65	156·5	8·04
30	169·05	0·66	−3·18	−5·25	6·14	148·8	2·91
31	181·24	0·64	−4·40	−6·03	7·46	143·9	357·64
Apr. 1	193·43	0·61	−5·42	−6·55	8·50	140·4	352·43
2	205·63	0·59	−6·17	−6·78	9·17	137·7	347·54
3	217·83	0·56	−6·59	−6·69	9·39	135·4	343·17
4	230·04	0·54	−6·63	−6·25	9·11	133·3	339·57
5	242·26	0·51	−6·27	−5·46	8·31	131·0	336·92
6	254·48	0·49	−5·53	−4·33	7·03	128·1	335·47
7	266·71	0·47	−4·45	−2·90	5·31	123·1	335·39
8	278·93	0·45	−3·12	−1·26	3·36	112·0	336·82
9	291·16	0·42	−1·61	+0·48	1·68	73·4	339·81
10	303·39	0·40	−0 05	+2·20	2·20	1·3	344·21
11	315·61	0·38	+1·47	+3·77	4·05	338·7	349·74
12	327·83	0·35	+2·85	+5·07	5·81	330·7	355·93
13	340·03	0·33	+4·04	+6·04	7·27	326·2	2·26
14	352·23	0·30	+4·96	+6·61	8·27	323·1	8·26
15	4·43	0·28	+5·60	+6·80	8·81	320·5	13·59
16	16·62	0·25	+5·96	+6·60	8·89	317·9	17·98
17	28·80	0·22	+6·03	+6·05	8·54	315·1	21·33
18	40·98	0·19	+5·82	+5·20	7·81	311·8	23·57
19	53·16	0·16	+5·36	+4·10	6·75	307·4	24·65
20	65·34	0·13	+4·67	+2·83	5·47	301·3	24·59
21	77·51	+0·10	+3·77	+1·44	4·04	290·9	23·43

Greenwich Midnight.	Selenographical Colong.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.	C.
1902.	°	°	°	°	°	°	°
Apr. 22	89·68	+0·07	+2·71	0·00	2·71	270·0	21·24
23	101·86	0·04	+1·51	−1·43	2·08	226·6	18·08
24	114·04	+0·01	+0·22	−2·77	2·78	184·5	14·10
25	126·22	−0·02	−1·14	−4·00	4·16	164·1	9·49
26	138·40	0·05	−2·49	−5·05	5·63	153·8	4·45
27	150·59	0·08	−3·80	−5·88	7·00	147·1	359·21
28	162·78	0·11	−5·00	−6·47	8·18	142·3	354·00
29	174 98	0·14	−6·03	−6·79	9·08	138·4	349·05
30	187·18	0·16	−6·81	−6·79	9·61	134·9	344·58
May 1	199·39	0·19	−7·29	−6·48	9·75	131·6	340·76
2	211·61	0·22	−7·41	−5·82	9·42	128·1	337·80
3	223·83	0·24	−7·12	−4·83	8·60	124·1	335·89
4	236·06	0·26	−6·41	−3·53	7·31	118·8	335·22
5	248·30	0·29	−5·29	−1·98	5·65	110·5	335·99
6	260·54	0·31	−3·82	−0·25	3·83	93·7	338·32
7	272·78	0·33	−2·07	+1·52	2·57	53·7	342·20
8	285·03	0·36	−0·18	+3·19	3·20	3·2	347·43
9	297·27	0·38	+1·72	+4·65	4·96	339·7	353·61
10	309·50	0·40	+3·48	+5·76	6·73	328·9	0·18
11	321·74	0·42	+4·97	+6·48	8·17	322·5	6·54
12	333·96	0·45	+6·11	+6·77	9·12	317·9	12·26
13	346·18	0·47	+6·85	+6·66	9·55	314·2	17·02
14	358·39	0·50	+7·16	+6·17	9·46	310·8	20·67
15	10·60	0·52	+7·09	+5·37	8·89	307·1	23·18
16	22·80	0·55	+6·68	+4·33	7·96	302·9	24·52
17	35·00	0·58	+5·96	+3·09	6·71	297·4	24·73
18	47·19	0·61	+5·02	+1·74	5·31	289·1	23·83
19	59·38	0·64	+3·89	+0·32	3·90	274·7	21·89
20	71·57	0·67	+2·65	−1·09	2·87	247·6	18·99
21	83·76	0·70	+1·33	−2·45	2·79	208·5	15·21
22	95·95	0·72	−0·02	−3·69	3·69	179·7	10·74
23	108·14	0·75	−1·38	−4·77	4·96	163·9	5·78
24	120·33	0·77	−2·69	−5·65	6·26	154·5	0·56
25	132·52	0·80	−3·94	−6·29	7·43	147·9	355·34
26	144·72	0·82	−5·08	−6·66	8·37	142·7	350·31
27	156·92	0·85	−6 05	−6·73	9·05	138·0	345·74
28	169·13	0·87	−6·84	−6·50	9·43	133·5	341·78
29	181·34	−0·89	−7·36	−5·95	9·47	129 0	338·60

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Geocentric Libration Combined Amount.	Geocentric Libration Direction.	C.
1902.	°	°	°	°	°	°	°
May 30	193·55	−0·91	−7·57	−5·09	9·12	123·9	336·39
31	205·78	0·93	−7·41	−3·93	8·38	117·9	335·29
June 1	218·01	0·95	−6·86	−2·52	7·31	110·2	335·49
2	230·25	0·96	−5·87	−0·91	5·94	98·8	337·12
3	242·49	0·98	−4·48	+0·81	4·55	79·8	340·29
4	254·74	1·00	−2·73	+2·50	3·70	47·5	344·94
5	266·99	1·01	−0·74	+4·04	4·11	10·4	350·80
6	279·25	1·03	+1·33	+5·30	5·47	345·9	357·37
7	291·50	1·05	+3·32	+6·17	7·01	331·7	4·06
8	303·75	1·07	+5·06	+6·61	8·32	322·6	10·26
9	315·99	1·08	+6·42	+6·61	9·22	315·8	15·56
10	328·23	1·10	+7·30	+6·20	9·57	310·3	19·70
11	340·46	1·12	+7·69	+5·46	9·43	305·4	22·63
12	352·68	1·14	+7·61	+4·45	8·81	300·3	24·31
13	4·90	1·16	+7·13	+3·24	7·83	294·4	24·80
14	17·11	1·18	+6·31	+1·91	6·59	286·8	24·15
15	29·32	1·20	+5·23	+0·53	5·26	275·8	22·46
16	41·52	1·22	+3·99	−0·87	4·08	257·7	19·77
17	53·73	1·24	+2·65	−2·21	3·45	230·2	16·20
18	65·92	1·26	+1·26	−3·45	3·67	200·1	11·90
19	78·12	1·27	−0·10	−4·54	4·54	178·7	7·03
20	90·31	1·29	−1·41	−5·44	5·62	165·5	1·85
21	102·51	1·31	−2·63	−6·10	6·64	156·7	356·57
22	114·70	1·32	−3·76	−6·50	7·51	149·9	351·46
23	126·90	1·34	−4·75	−6·61	8·14	144·3	346·74
24	139·10	1·35	−5·60	−6·42	8·52	138·9	342·63
25	151·31	1·36	−6·28	−5·92	8·63	133·3	339·27
26	163·51	1·37	−6·76	−5·13	8·49	127·2	336·83
27	175·72	1·38	−6·98	−4·06	8·08	120·2	335·46
28	187·94	1·39	−6·91	−2·75	7·51	113·1	335·27
29	200·17	1·40	−6·50	−1·25	6·62	100·9	336·41
30	212·40	1·41	−5·70	+0·36	5·71	86·4	338·95
July 1	224·64	1·41	−4·52	+1·99	4·94	66·2	342·92
2	236·89	1·42	−2·97	+3·52	4·61	40·2	348·21
3	249·14	1·42	−1·13	+4·84	4·97	13·1	354·46
4	261·40	1·43	+0·86	+5·83	5·89	351·6	1·15
5	273·66	1·44	+2·83	+6·40	7·00	336·1	7·68
6	285·91	−1·45	+4·61	+6·53	7·99	324·8	13·51

Greenwich Midnight.	Selenographical Colong.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.	C.
1902.	°	°	°	°	°	°	°
July 7	298·16	−1·45	+6·03	+6·23	8·68	315·9	18·25
8	310·41	1·46	+7·00	+5·55	8·93	308·4	21·74
9	322·65	1·47	+7·47	+4·57	8·76	301·5	23·90
10	334·88	1·48	+7·44	+3·38	8·17	294·4	24·79
11	347·11	1·49	+6·97	+2·05	7·26	286·4	24·47
12	359·33	1·49	+6·14	+0·65	6·17	276·0	23·02
13	11·55	1·50	+5·05	−0·74	5·10	261·7	20·56
14	23·76	1·51	+3·77	−2·08	4·31	241·1	17·20
15	35·97	1·51	+2·41	−3·32	4·10	216·0	13·07
16	48·18	1·52	+1·04	−4·41	4·53	193·3	8·33
17	60·38	1·52	−0·28	−5·31	5·32	177·0	3·20
18	72·58	1·53	−1·51	−5·99	6·18	165·8	357·91
19	84·77	1·53	−2·60	−6·41	6·92	157·9	352·70
20	96·96	1·53	−3·55	−6·54	7·44	151·5	347·83
21	109·16	1·53	−4·33	−6·37	7·70	145·8	343·50
22	121·35	1·53	−4·97	−5·89	7·71	139·8	339·94
23	133·54	1·53	−5·43	−5·12	7·46	133·3	337·27
24	145·74	1·53	−5·72	−4·08	7·03	125·5	335·65
25	157·94	1·53	−5·82	−2·81	6·46	115·8	335·19
26	170·15	1·52	−5·70	−1·36	5·86	103·4	335·99
27	182·36	1·52	−5·31	+0·19	5·31	88·0	338·13
28	194·58	1·51	−4·64	+1·77	4·97	69·1	341·61
29	206·81	1·51	−3·65	+3·26	4·90	48·2	346·35
30	219·05	1·50	−2·36	+4·58	5·15	27·3	352·13
31	231·29	1·49	−0·83	+5·61	5·67	8·4	358·54
Aug. 1	243·53	1·49	+0·86	+6·28	6·34	352·2	5·07
2	255·79	1·48	+2·56	+6·52	7·00	338·6	11·19
3	268·04	1·48	+4·11	+6·33	7·55	327·0	16·42
4	280·29	1·47	+5·39	+5·73	7·86	316·8	20·49
5	292·54	1·47	+6·28	+4·80	7·91	307·4	23·22
6	304·78	1·47	+6·71	+3·61	7·62	298·3	24·62
7	317·02	1·46	+6·69	+2·26	7·06	288·7	24·73
8	329·25	1·46	+6·25	+0·84	6·31	277·7	23·62
9	341·48	1·45	+5·44	−0·59	5·47	263·8	21·43
10	353·70	1·45	+4·38	−1·96	4·80	245·9	18·29
11	5·92	1·44	+3·13	−3·23	4·50	224·1	14·33
12	18·13	1·43	+1·79	−4·35	4·71	202·4	9·75
13	30·33	−1·43	+0·46	−5·28	5·30	185·0	4·71

Greenwich Midnight.	Selenographical Colong.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.	C.
1902.	°	°	°	°	°	°	°
Aug. 14	42·53	−1·42	−0·80	−5·98	6·03	172·4	359·45
15	54·72	1·41	−1·93	−6·43	6·71	163·3	354·18
16	66·92	1·40	−2·88	−6·59	7·19	156·4	349·17
17	79·10	1·39	−3·65	−6·45	7·41	150·5	344·64
18	91·29	1·37	−4·19	−6·00	7·32	145·1	340·80
19	103·47	1·36	−4·55	−5·24	6·94	139·0	337·84
20	115·65	1·34	−4·70	−4·20	6·31	131·8	335·92
21	127·84	1·33	−4·68	−2·92	5·52	122·0	335·17
22	140·03	1·31	−4·49	−1·46	4·72	108·0	335·70
23	152·22	1·29	−4·13	+0·10	4·13	88·6	337·55
24	164·42	1·27	−3·59	+1·68	3·96	64·9	340·72
25	176·62	1·26	−2·87	+3·18	4·29	42·1	345·13
26	188·83	1·24	−1·96	+4·50	4·91	23·5	350·56
27	201·04	1·22	−0·88	+5·56	5·63	9·0	356·68
28	213·27	1·20	+0·35	+6·28	6·29	356·8	3·05
29	225·50	1·19	+1·64	+6·60	6·80	346·0	9·18
30	237·73	1·17	+2·92	+6·50	7·13	335·8	14·63
31	249·97	1·15	+4·08	+6·00	7·26	325·8	19·09
Sept. 1	262·22	1·14	+4·98	+5·14	7·16	315·9	22·32
2	274·46	1·12	+5·59	+3·98	6·87	305·5	24·25
3	286·70	1·11	+5·83	+2·63	6·40	294·3	24·84
4	298·93	1·09	+5·70	+1·18	5·82	281·7	24·17
5	311·16	1·08	+5·21	−0·31	5·22	266·6	22·33
6	323·38	1·06	+4·41	−1·74	4·74	248·5	19·46
7	335·60	1·04	+3·36	−3·07	4·55	227·6	15·72
8	347·81	1·02	+2·15	−4·24	4·75	206·9	11·29
9	0·02	1·01	+0·83	−5·23	5·30	189·0	6·35
10	12·22	0·99	−0·46	−5·99	6·01	175·6	1·14
11	24·41	0·97	−1·68	−6·49	6·70	165·5	355·87
12	36·61	0·95	−2·76	−6·72	7·26	157·7	350·78
13	48·79	0·93	−3·63	−6·64	7·57	151·3	346·07
14	60·97	0·90	−4·25	−6·25	7·56	145·8	341·98
15	73·15	0·88	−4·60	−5·55	7·21	140·3	338·69
16	85·32	0·85	−4·69	−4·53	6·52	134·0	336·39
17	97·49	0·83	−4·51	−3·26	5·57	125·9	335·25
18	109·65	0·80	−4·11	−1·78	4·48	113·4	335·40
19	121·82	0·77	−3·50	−0·17	3·50	92·8	336·93
20	133·99	−0·75	−2·74	+1·47	3·11	61·8	339·84

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1902.	°	°	°	°	°	°	°
Sept. 21	146·17	−0·72	−1·86	+3·04	3·57	31·5	341·04
22	158·35	0·69	−0·89	+4·42	4·51	11·4	349·31
23	170·53	0·66	+0·14	+5·54	5·54	358·6	355·30
24	182·73	0·64	+1·18	+6·31	6·42	349·4	1·58
25	194·93	0·61	+2·21	+6·70	7·06	341·7	7·70
26	207·14	0·59	+3·16	+6·68	7·39	334·7	13·24
27	219·35	0·56	+4·01	+6·27	7·44	327·4	17·90
28	231·57	0·54	+4·67	+5·49	7·21	319·6	21·45
29	243·79	0·52	+5·13	+4·40	6·76	310·6	23·75
30	256·01	0·50	+5·32	+3·09	6·15	300·2	24·79
Oct. 1	268·24	0·47	+5·24	+1·64	5·49	287·4	24·56
2	280·46	0·45	+4·88	+0·13	4·88	271·5	23·12
3	292·68	0·43	+4·25	−1·34	4·46	252·5	20·59
4	304·90	0·40	+3·37	−2·75	4·35	230·8	17·10
5	317·11	0·38	+2·29	−4·00	4·61	209·8	12·84
6	329·32	0·35	+1·08	−5·06	5·18	192·1	8·03
7	341·52	0·33	−0·22	−5·89	5·89	177·9	2·88
8	353·72	0·30	−1·51	−6·48	6·65	166·9	357·62
9	5·91	0·28	−2·74	−6·78	7·31	158·0	352·48
10	18·09	0·25	−3·83	−6·80	7·81	150·6	347·67
11	30·27	0·22	−4·69	−6·50	8·01	144·2	343·38
12	42·45	0·19	−5·29	−5·90	7·93	138·1	339·81
13	54·61	0·16	−5·57	−4·98	7·47	131·8	337·12
14	66·77	0·13	−5·51	−3·78	6·68	124·4	335·52
15	78·93	0·10	−5·09	−2·34	5·60	114·7	335·17
16	91·08	0·07	−4·35	−0·72	4·41	99·4	336·21
17	103·23	0·04	−3·32	+0·97	3·46	73·7	338·69
18	115·38	−0·01	−2·18	+2·63	3·42	39·7	342·60
19	127·53	+0·03	−0·72	+4·12	4·18	9·9	347·73
20	139·69	0·06	+0·68	+5·35	5·39	352·8	353·73
21	151·85	0·09	+2·02	+6·23	6·55	342·0	0·11
22	164·02	0·12	+3·23	+6·70	7·44	334·3	6·38
23	176·19	0·15	+4·24	+6·76	7·98	327·9	12·11
24	188·38	0·17	+5·03	+6·42	8·16	321·9	16·95
25	200·57	0·20	+5·55	+5·72	7·97	315·9	20·72
26	212·76	0·22	+5·82	+4·70	7·48	308·9	23·31
27	224·96	0·25	+5·84	+3·46	6·79	300·7	24·66
28	237·16	+0·27	+5·61	+2·05	5·97	290·1	24·77

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.	C.
1902.	°	°	°	°	°	°	°
Oct. 29	249·37	+0·30	+5·15	+0·57	5·18	276·3	23·69
30	261·58	0·32	+4·49	−0·92	4·58	258·4	21·51
31	273·78	0·34	+3·64	−2·35	4·33	237·2	18·31
Nov. 1	285·99	0·37	+2·63	−3·65	4·50	215·8	14·28
2	298·19	0·39	+1·48	−4·77	4·99	197·2	9·60
3	310·39	0·42	+0·24	−5·67	5·68	182·4	4·51
4	322·58	0·44	−1·06	−6·32	6·41	170·5	359·37
5	334·77	0·47	−2·37	−6·70	7·11	160·5	354·07
6	346·96	0·49	−3·62	−6·80	7·70	152·0	349·17
7	359·14	0·52	−4·75	−6·60	8·13	144·3	344·76
8	11·31	0·55	−5·69	−6·11	8·35	137·0	340·98
9	23·48	0·58	−6·37	−5·32	8·30	129·9	338·02
10	35·64	0·60	−6·73	−4·25	7·96	122·3	336·02
11	47·80	0·63	−6·69	−2·92	7·30	113·6	335·14
12	59·94	0·66	−6·23	−1·39	6·38	102·6	335·57
13	72·08	0·69	−5·33	+0·27	5·34	87·1	337·43
14	84·22	0·72	−4·04	+1·96	4·49	64·1	340·77
15	96·35	0·75	−2·42	+3·55	4·30	34·3	345·44
16	108·48	0·78	−0·60	+4·91	4·95	7·0	351·41
17	120·62	0·80	+1·27	+5·93	6·07	347·9	357·94
18	132·76	0·83	+3·05	+6·54	7·22	335·0	4·53
19	144·90	0·85	+4·59	+6·70	8·12	325·6	10·65
20	157·05	0·87	+5·79	+6·44	8·67	318·0	15·87
21	169·21	0·90	+6·61	+5·80	8·80	311·3	19·97
22	181·38	0·92	+7·03	+4·84	8·53	304·5	22·85
23	193·56	0·94	+7·08	+3·65	7·97	297·3	24·47
24	205·74	0·96	+6·80	+2·29	7·17	288·6	24·86
25	217·92	0·98	+6·25	+0·85	6·31	277·7	24·08
26	230·10	0·99	+5·48	−0·61	5·51	263·6	22·17
27	242·29	1·01	+4·54	−2·02	4·97	246·0	19·25
28	254·49	1·03	+3·48	−3·32	4·81	226·4	15·46
29	266·68	1·05	+2·32	−4·46	5·03	207·5	10·95
30	278·87	1·07	+1·08	−5·39	5·50	191·3	5·96
Dec. 1	291·06	1·08	−0·20	−6·09	6·09	178·1	0·71
2	303·25	1·10	−1·50	−6·52	6·69	167·0	355·48
3	315·44	1·12	−2·80	−6·67	7·23	157·2	350·48
4	327·62	1·14	−4·04	−6·53	7·68	148·3	345·94
5	339·79	+1·16	−5·20	−6·11	8·02	139·6	342·01

Greenwich Midnight.	Selenographical Colong.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Sel. Lat. of the Earth.	Geocentric Libration Combined Amount.	Geocentric Libration Direction.	C.
1902.	°	°	°	°	°	°	°
Dec. 6	351·97	+1·18	−6·21	−5·41	8·24	131·1	338·84
7	4·13	1·20	−6·99	−4·45	8·29	122·5	336 57
8	16·29	1·22	−7·48	−3·25	8·16	113·5	335·31
9	28·44	1·24	−7·60	−1·84	7·82	103·6	335·23
10	40·59	1·26	−7·28	−0·29	7·29	92·3	336·44
11	52·73	1·28	−6·47	+1·33	6·61	78·4	339·07
12	64·86	1·29	−5·18	+2·91	5·94	60·7	343·15
13	76·99	1·31	−3·46	+4·34	5·55	38·6	348·56
14	89·11	1·33	−1·41	+5·49	5·67	14·4	354·93
15	101·23	1·35	+0·77	+6·25	6·30	353·0	1·72
16	113·35	1·36	+2·91	+6·56	7·17	336·1	8·31
17	125·48	1·37	+4·80	+6·41	8·01	323·2	14·13
18	137·62	1·39	+6·29	+5·83	8·58	312·8	18·81
19	149·76	1·40	+7·31	+4·91	8·81	303·9	22·18
20	161·91	1·41	+7·83	+3·73	8·68	295·5	24·18
21	174·06	1·41	+7·87	+2·39	8·23	286·9	24·89
22	186·22	1·42	+7·50	+0·96	7·56	277·3	24·36
23	198·39	1·43	+6·81	−0·48	6·83	266 0	22·69
24	210·56	1·43	+5·87	−1·87	6·16	252·3	20·00
25	222·74	1·44	+4·76	−3·16	5·72	236·4	16·43
26	234·92	1·45	+3·54	−4·29	5·56	219·5	12·10
27	247·10	1·45	+2·26	−5·22	5·69	203·4	7·23
28	259·29	1·46	+0·97	−5·93	6·01	189·3	2·04
29	271·47	1·47	−0·33	−6·37	6·38	177·0	356·77
30	283·66	1·47	−1·60	−6·55	6·74	166·3	351·68
31	295·85	1·48	−2·83	−6·43	7·03	156·2	346·99
1903.							
Jan. 1	308·03	+1·48	−4·01	−6·04	7·25	146·4	342·88

The longitudes are reckoned in the plane of the Moon's equator, the axis of reference being the radius which passes through the mean centre of the visible disc. This axis therefore rotates with the Moon, and is not fixed in space.

The inclination of the Moon's equator to the ecliptic is taken as 1°·523, the value used in the *Connaissance des Temps*, that given by the *Nautical Almanac* being 1°·536.

The physical librations in longitude and latitude, as given by Professor Franz's formulæ, have been applied; their values are taken from the *Berliner Jahrbuch* for the days given there, and interpolated by a graphical method for the other days. But the signs in the *Jahrbuch* require to be reversed in order to reduce to the system used here.

The colongitude of the Sun is 90° (or 450°) *minus* his selenographical longitude. It also is the selenographical longitude of the morning terminator reckoned eastward from the mean centre of the disc. Hence its value is approximately 270°, 0°, 90°, 180° at new Moon, first quarter, full Moon, last quarter respectively. The longitude of the evening terminator is of course 180° greater or less than that of the morning one.

When the geocentric libration in longitude is positive, the region brought into view is on the west limb; when negative, on the east.

When the geocentric libration in latitude is positive, the region brought into view is at the Moon's north pole; when negative, at the south.

The column "Combined Amount" gives the distance between the apparent and mean centres of the disc, and the column "Direction" gives the position-angle of the apparent centre from the mean centre, or, which is the same thing, the position-angle of the region which is most carried into view by libration. The angles are reckoned eastward from the northern extremity of the Moon's axis.

C denotes the geocentric position-angle of the northern extremity of the Moon's axis measured eastward from the northernmost point of the disc. It has been computed by the second formula given in the Preface to the *Nautical Almanac*, but the co-ordinates of the Moon's equator have been taken from the *Connaissance des Temps*, so as to make this column consistent with the rest of the ephemeris.

The terms "East" and "West" are used throughout with reference to our sky, and not as they would appear to an observer on the Moon.

I give the method for finding the altitude of the Sun at a given point on the Moon whose position is defined: (1) by selenographical longitude and latitude; (2) by direction cosines.

In either case the Sun's selenographical colongitude and latitude (K, L supposed) must be found by interpolation from the ephemeris for the given time.

In the first case let the given point be in the position longitude M, latitude N. Longitudes are reckoned from the meridian passing through the mean centre of the disc, and the positive direction is that towards Mare Crisium. North latitudes are considered positive.

Then

$$\text{sine Sun's altitude} = \sin L \sin N + \cos L \cos N \sin (K + M).$$

In the second case let ξ, η, ζ be the direction cosines of the given point. The axes are (1) that diameter of the Moon's equator which is 90° from the mean centre of the disc; (2) the Moon's polar axis; (3) the diameter through the mean centre of the disc. The positive directions are as above. Mr. Saunder

has issued some maps of portions of the Moon's surface from which the co-ordinates ξ, η, ζ can be taken at sight.

Then the Sun's direction cosines are :

$$\cos K \cos L, \sin L, \sin K \cos L,$$

and sine Sun's altitude

$$= \xi \cos K \cos L + \eta \sin L + \zeta \sin K \cos L.$$

Neither formula is convenient when the Sun's altitude is very great, for an angle near 90° cannot be accurately determined from its sine. However, when the Sun is high the shadows are so inconspicuous that it is not necessary to compute his altitude with great accuracy.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.*
1901 *September* 21.

Ephemeris for Physical Observations of

Greenwich Noon.	P.	L−O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1902.	°	°	°	′	″	″	°	°	°
Feb. 21	344·765	167·836	−0·822	33·46	0·07	31·31	5·31	255·90	−0·88
23	344·604	168·275	−0·803	33·55	·08	31·39	5·57	255·78	−0·86
25	344·446	168·712	−0·785	33·65	·09	31·48	5·84	255·66	−0·84
27	344·290	169·145	−0·767	33·74	·10	31·57	6·10	255·54	−0·82
Mar. 1	344·137	169·573	−0·749	33·85	·10	31·67	6·36	255·42	−0·80
3	343·987	169·999	−0·731	33·96	·11	31·77	6·61	255·31	−0·78
5	343·839	170·420	−0·713	34·07	·12	31·87	6·86	255·19	−0·76
7	343·694	170·837	−0·695	34·19	·13	31·98	7·11	255·08	−0·74
9	343·551	171·249	−0·677	34·31	·14	32·10	7·35	254·97	−0·72
11	343·410	171·656	−0·659	34·44	·15	32·22	7·59	254·86	−0·70
13	343·272	172·059	−0·641	34·58	·16	32·35	7·82	254·75	−0·68
15	343·137	172·456	−0·623	34·72	·17	32·48	8·04	254·64	−0·67
17	343·004	172·849	−0·605	34·86	·18	32·61	8·27	254·54	−0·65
19	342·874	173·234	−0·587	34·99	·19	32·74	8·48	254·43	−0·63
21	342·748	173·615	−0·570	35·14	·20	32·87	8·69	254·33	−0·61
23	342·624	173·990	−0·552	35·29	·21	33·02	8·89	254·23	−0·59
25	342·502	174·358	−0·535	35·45	·22	33·17	9·09	254·13	−0·57
27	342·383	174·720	−0·517	35·62	·23	33·33	9·28	254·04	−0·55
29	342·268	175·076	−0·500	35·79	·24	33·49	9·46	253·95	−0·53
31	342·156	175·425	−0·483	35·96	·25	33·65	9·64	253·86	−0·52
Apr. 2	342·046	175·766	−0·466	36·14	·26	33·82	9·81	253·77	−0·50
4	341·939	176·102	−0·449	36·33	·27	33·99	9·97	253·68	−0·48
6	341·835	176·428	−0·432	36·52	·28	34·17	10·13	253·59	−0·46
8	341·734	176·748	−0·415	36·71	·29	34·35	10·28	253·50	−0·44
10	341·637	177·060	−0·398	36·91	·30	34·53	10·42	253·42	−0·43
12	341·543	177·363	−0·381	37·12	·31	34·72	10·55	253·34	−0·41
14	341·452	177·659	−0·365	37·32	·32	34·92	10·67	253·27	−0·39
16	341·364	177·946	−0·349	37·53	·33	35·12	10·79	253·20	−0·37
18	341·279	178·223	−0·333	37·75	·34	35·32	10·89	253·13	−0·36
20	341·197	178·492	−0·317	37·97	·34	35·52	10·99	253·06	−0·34
22	341·119	178·753	−0·301	38·19	·35	35·73	11·08	253·00	−0·32
24	341·044	179·002	−0·286	38·41	·36	35·94	11·15	252·94	−0·31
26	340·972	179·244	−0·271	38·64	·37	36·16	11·22	252·89	−0·29
28	340·903	179·474	−0·256	38·88	·37	36·38	11·28	252·84	−0·27
30	340·837	179·696	−0·242	39·12	0·38	36·60	11·33	252·80	−0·26

Jupiter, 1902–3. By A. C. D. Crommelin.

Greenwich Noon. 1902.	Longitude of Y's Central Meridian. 877°90 I.	870°27 II.	Corr. for Phase.	Light-time.	A−O.	B.
	°	°	°	m	°	°
Feb. 21	170·69	346·30	+0·12	49·645	162·528	−0·920
23	126·13	286·48	·14	49·513		
25	81·58	226·67	·15	49·375		
27	37·04	166·86	·16	49·232		
Mar. 1	352·50	107·06	·18	49·079		
3	307·97	47·27	·19	48·921	163·382	−0·877
5	263·45	347·49	·20	48·759		
7	218·94	287·72	·22	48·592		
9	174·43	227·95	·24	48·419		
11	129·93	168·19	·25	48·240		
13	85·44	108·44	·27	48·055	164·239	−0·833
15	40·96	48·70	·28	47·866		
17	356·49	348·97	·30	47·672		
19	312·02	289·24	·31	47·474		
21	267·56	229·52	·33	47·271		
23	223·11	169·81	·34	47·062	165·097	−0·788
25	178·67	110·11	·36	46·849		
27	134·24	50·42	·38	46 632		
29	89·82	350·74	·39	46·413		
31	45·41	291·07	·40	46·189		
Apr. 2	1·01	231·40	·42	45·958	165·956	−0·744
4	316·62	171·75	·43	45·725		
6	272·24	112·11	·45	45·489		
8	227·86	52·47	·46	45·250		
10	183·49	352·84	·47	45·008		
12	139·14	293·22	·48	44·763	166·816	−0·699
14	94·80	233·62	·49	44·515		
16	50·47	174·03	·51	44·265		
18	6·14	114·44	·52	44·013		
20	321·82	54·86	·53	43·759		
22	277·52	355·30	·54	43·502	167·676	−0·654
24	233·23	295·75	·54	43·242		
26	188·95	236·21	·55	42·982		
28	144·68	176·68	·55	42·722		
30	100·41	117·15	+0·56	42·460		

Greenwich Noon.	P.	L−O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1902.	°	°	°	″	″	″	°	°	°
May 2	340·775	179·908	−0·228	39·37	0·38	36·83	11·37	252·75	−0·24
4	340·716	180·109	−0·214	39·62	·39	37·06	11·40	252·71	−0·23
6	340·660	180·298	−0·200	39·87	·39	37·29	11·42	252·67	−0·21
8	340·608	180·477	−0·187	40·12	·40	37·53	11·42	252·64	−0·20
10	340·559	180·645	−0·174	40·38	·40	37·77	11·42	252·61	−0·19
12	340·513	180·801	−0·161	40·64	·40	38·01	11·40	252·59	−0·17
14	340·471	180·947	−0·148	40·90	·40	38·26	11·37	252·57	−0·16
16	340·432	181·081	−0·136	41·16	·40	38·51	11·33	252·56	−0·14
18	340·397	181·203	−0·124	41·43	·40	38·76	11·28	252·54	−0·13
20	340·365	181·312	−0·113	41·70	·40	39·01	11·22	252·53	−0·12
22	340·337	181·410	−0·102	41·97	·40	39·26	11·14	252·52	−0·11
24	340·312	181·496	−0·091	42·25	·39	39·51	11·06	252·51	−0·10
26	340·291	181·569	−0·080	42·52	·39	39·77	10·96	252·51	−0·09
28	340·273	181·631	−0·070	42·79	·38	40·03	10·85	252·52	−0·08
30	340·258	181·679	−0·060	43·06	·38	40·29	10·72	252·52	−0·06
June 1	340·247	181·715	−0·051	43·34	·37	40·55	10·59	252·53	−0·05
3	340·240	181·739	−0·042	43·62	·36	40·81	10·44	252·55	−0·04
5	340·236	181·749	−0·034	43·89	·35	41·07	10·27	252·58	−0·04
7	340·236	181·746	−0·026	44·16	·34	41·32	10·10	252·62	−0·03
9	340·239	181·731	−0·018	44·43	·33	41·57	9·91	252·66	−0·02
11	340·246	181·703	−0·011	44·70	·32	41·82	9·71	252·71	−0·01
13	340·257	181·663	−0·004	44·97	·31	42·07	9·49	252·76	0·00
15	340·271	181·608	+0·002	45·23	·30	42·32	9·26	252·82	0·00
17	340·289	181·543	+0·007	45·49	·29	42·56	9·02	252·89	+0·01
19	340·310	181·465	+0·012	45·74	·27	42·80	8·77	252·97	+0·01
21	340·335	181·374	+0·017	45·99	·26	43·03	8·51	253·05	+0·02
23	340·364	181·272	+0·021	46·24	·25	43·26	8·23	253·13	+0·02
25	340·395	181·158	+0·025	46·49	·23	43·49	7·94	253·22	+0·03
27	340·430	181·031	+0·029	46·72	·21	43·71	7·64	253·31	+0·03
29	340·468	180·893	+0·032	46·95	·19	43·92	7·33	253·41	+0·03
July 1	340·509	180·744	+0·034	47·17	·18	44·12	7·01	253·53	+0·04
3	340·554	180·585	+0·036	47·38	·16	44·32	6·68	253·66	+0·04
5	340·602	180·415	+0·038	47·58	·14	44·51	6·33	253·81	+0·04
7	340·652	180·235	+0·039	47·77	·13	44·70	5·98	253·97	+0·04
9	340·706	180·045	+0·040	47·95	·12	44·87	5·61	254·15	+0·04
11	340·763	179·846	+0·040	48·12	·10	45·03	5·24	254·36	+0·04
13	340·823	179·638	+0·039	48·29	·09	45·18	4·86	254·59	+0·04
15	340·886	179·423	+0·038	48·45	0·07	45·33	4·47	254·84	+0·04

Greenwich Noon. 1900.		Longitude of ℓ's Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A – O.	B.
		°	°	°	m	°	°
May	2	56·16	57·63	+0·56	42·197	168·539	−0·609
	4	11·92	358·13	·56	41·933		
	6	327·69	298·64	·57	41·670		
	8	283·47	239·16	·57	41·407		
	10	239·26	179·69	·57	41·144		
	12	195·07	120·23	·56	40·881	169·401	−0·563
	14	150·88	60·78	·56	40·618		
	16	106·71	1·35	·56	40·356		
	18	62·55	301·93	·55	40·097		
	20	18·40	242·52	·55	39·839		
	22	334·26	183·11	·54	39·581	170·266	−0·518
	24	290·13	123·72	·53	39·325		
	26	246·01	64·34	·52	39·072		
	28	201·90	4·97	·51	38·823		
	30	157·80	305·61	·50	38·576		
June	1	113·71	246·26	·49	38·331	171·131	−0·472
	3	69·63	186·92	·47	38·090		
	5	25·56	127·59	·46	37·853		
	7	341·51	68·27	·44	37·619		
	9	297·47	8·96	·43	37·390		
	11	253·44	309·67	·41	37·165	172·000	−0·426
	13	209·41	250·38	·39	36·945		
	15	165·39	191·10	·37	36·730		
	17	121·38	131·83	·35	36·520		
	19	77·39	72·58	·33	39·316		
	21	33·40	13·34	·31	36·117	172·867	−0·380
	23	349·42	314·10	·29	35·925		
	25	305·45	254·87	·28	35·740		
	27	261·49	195·65	·26	35·561		
	29	217·53	136·43	·24	35·389		
July	1	173·58	77·21	·21	35·223	173·736	−0·333
	3	129·63	18·00	·19	35·065		
	5	85·69	318·80	·17	34·915		
	7	41·76	259·61	·16	34·773		
	9	357·84	200·42	·14	34·639		
	11	313·91	141·23	·12	34·513	174·606	−0·287
	13	269·99	82·05	·10	34·395		
	15	226·07	22·87	+0·09	34·288		

Greenwich Noon.	P.	L—O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1902.	°	°	°	″	″	″	°	°	°
July 17	340·952	179·200	+0·037	48·59	0·06	45·46	4·07	255·14	+0·04
19	341·020	178·972	+0·035	48·72	·05	45·58	3·67	255·50	+0·04
21	341·091	178·735	+0·033	48·84	·04	45·69	3·26	255·93	+0·04
23	341·163	178·494	+0·030	48·94	·03	45·79	2·84	256·45	+0·03
25	341·237	178·248	+0·027	49·03	·02	45·87	2·42	257·12	+0·03
27	341·313	177·998	+0·024	49·10	·01	45·94	2·00	258·16	+0·03
29	341·390	177·743	+0·020	49·16	·01	46·00	1·58	259·57	+0·02
31	341·467	177·486	+0·016	49·21	·01	46·05	1·15	263·72	+0·02
Aug. 2	341·546	177·227	+0·012	49·25	·00	46·08	0·72	268·54	+0·01
4	341·625	176·967	+0·008	49·27	·00	46·10	0·32	287·32	+0·00
6	341·706	176·706	+0·003	49·28	·00	46·10	0·25	27·59	0·00
8	341·787	176·445	−0·002	49·27	·00	46·10	0·63	57·32	0·00
10	341·867	176·186	−0·007	49·24	·00	46·07	1·06	64·08	−0·01
12	341·948	175·928	−0·012	49·20	·01	46·04	1·49	66·98	−0·01
14	342·028	175·674	−0·017	49·15	·01	45·99	1·91	68·62	−0·02
16	342·109	175·422	−0·023	49·08	·02	45·93	2·33	69·72	−0·02
18	342·188	175·174	−0·029	49·00	·03	45·86	2·76	70·47	−0·03
20	342·266	174·932	−0·035	48·90	·04	45·77	3·17	71·04	−0·04
22	342·342	174·694	−0·041	48·80	·05	45·67	3·59	71·51	−0·04
24	342·417	174·463	−0·048	48·69	·06	45·56	3·99	71·88	−0·05
26	342·490	174·238	−0·054	48·56	·07	45·44	4·39	72·19	−0·06
28	342·561	174·022	−0·060	48·41	·09	45·30	4·78	72·47	−0·06
30	342·630	173·812	−0·066	48·25	·10	45·15	5·17	72·72	−0·07
Sept. 1	342·696	173·611	−0·072	48·09	·11	44·99	5·54	72·93	−0·08
3	342·760	173·420	−0·078	47·92	·13	44·83	5·91	73·13	−0·08
5	342·821	173·237	−0·083	47·74	·15	44·65	6·27	73·31	−0·09
7	342·879	173·066	−0·089	47·54	·16	44·46	6·62	73·48	−0·10
9	342·933	172·904	−0·094	47·33	·18	44·27	6·96	73·62	−0·10
11	342·983	172·754	−0·099	47·11	·19	44·07	7·28	73·75	−0·11
13	343·030	172·615	−0·104	46·89	·21	43·87	7·60	73·88	−0·11
15	343·073	172·488	−0·109	46·66	·22	43·65	7·90	74·01	−0·12
17	343·112	172·372	−0·114	46·42	·23	43·43	8·19	74·13	−0·12
19	343·147	172·269	−0·119	46·18	·24	43·21	8·47	74·24	−0·13
21	343·178	172·178	−0·123	45·94	·26	42·98	8·73	74·34	−0·13
23	343·205	172·100	−0·127	45·69	·28	42·75	8·99	74·43	−0·14
25	343·227	172·034	−0·131	45·44	·29	42·51	9·23	74·50	−0·14
27	343·245	171·981	−0·135	45·18	·30	42·27	9·46	74·56	−0·14
29	343·258	171·941	−0·138	44·92	0·32	42·02	9·67	74·61	−0·15

Greenwich Noon.	Longitude of ♃'s Central Meridian. $877^{\circ}\cdot90$ I.	$870^{\circ}\cdot27$ II.	Corr. for Phase.	Light-time.	A—O.	B.
1902.	°	°	°	m	°	°
July 17	182·15	323·69	+0·07	34·190		
19	138·24	264·52	·06	34·100		
21	94·32	205·34	·05	34·019	175·478	−0·241
23	50·40	146·16	·04	33·947		
25	6·49	86·99	·03	33·884		
27	322·57	27·81	·02	33·831		
29	278 65	328·63	·01	33·788		
31	234 73	269·45	+ ·01	33·754	176·350	−0·194
Aug. 2	190·80	210·26	·00	33·730		
4	146·87	151·07	·00	33·716		
6	102·93	91·88	·00	33·712		
8	58·99	32·67	·00	33·718		
10	15·04	333·46	·00	33·734	177·223	−0·146
12	331·08	274·24	− ·01	33·760		
14	287·11	215·01	·02	33·796		
16	243·14	155·78	·02	33·842		
18	199·16	96·54	·03	33·897		
20	155·16	37·28	·04	33·961	178·097	−0·099
22	111·15	338·01	·06	34·035		
24	67·13	278·73	·07	34·118		
26	23·10	219·44	·08	34·212		
28	339·06	160·14	·10	34·312		
30	295·00	100·82	·12	34·422	178·972	−0·052
Sept. 1	250·93	41·49	·13	34·541		
3	206·84	342·15	·15	34·669		
5	162·74	282·79	·17	34·804		
7	118·62	223·41	·19	34·948		
9	74·49	164·02	·21	35·100	179·849	−0·005
11	30·34	104·61	·23	35·259		
13	346·18	45·19	·25	35·426		
15	302·00	345·75	·27	35·601		
17	257·81	286·30	·29	35·780		
19	213·60	226·83	·31	35·967	180·727	+0·042
21	169·37	167·34	·33	36·159		
23	125·12	107·84	·35	36·360		
25	80·86	48·32	·37	36·565		
27	36 59	348·79	·39	36·775		
29	352·30	289·24	−0·41	36·991	181·607	+0·089

Greenwich Noon.	P	L−O.	B.	Apparent Diameter. Equat. 2″.	Defect.	Polar 2b.	d.	Q.	B′.
1902.	° ′	°	°	″	″	″	°	°	°
Oct. 1	343·267	171·915	−0·141	44·65	0·33	41·77	9·88	74·65	−0·15
3	343·272	171·902	−0·143	44·38	·34	41·52	10·06	74·69	−0·15
5	343·272	171·902	−0·145	44·11	·35	41·27	10·24	74·72	−0·16
7	343·268	171·915	−0·147	43·84	·36	41·02	10·40	74·75	−0·16
9	343·259	171·942	−0·148	43·56	·37	40·76	10·55	74·77	−0·16
11	343·246	171·982	−0·149	43·29	·37	40·51	10·69	74·79	−0·16
13	343·228	172·035	−0·150	43·02	·38	40·25	10·81	74·81	−0·16
15	343·206	172·101	−0·150	42·75	·38	39·99	10·92	74·83	−0·16
17	343·179	172·181	−0·150	42·48	·39	39·74	11·02	74·84	−0·16
19	343·148	172·273	−0·149	42·21	·39	39·48	11·10	74·84	−0·16
21	343·113	172·376	−0·148	41·94	·39	39·23	11·17	74·83	−0·16
23	343·074	172·494	−0·147	41·67	·40	38 98	11·23	74·82	−0·16
25	343·031	172·623	−0·145	41·40	·40	38·73	11·28	74·81	−0·16
27	342·983	172·765	−0·143	41·14	·40	38·49	11·32	74·80	−0·15
29	342·931	172·919	−0·140	40·88	·40	38·25	11·34	74·78	−0·15
31	342·876	173·085	−0·137	40·62	·40	38·01	11·35	74·75	−0·15
Nov. 2	342·817	173·263	−0·133	40·36	·40	37·77	11·35	74·72	−0·14
4	342·754	173·451	−0·129	40·11	·39	37·54	11·34	74·69	−0·14
6	342·688	173·652	−0·125	39·86	·39	37·30	11·31	74·66	−0·13
8	342·618	173·864	−0·121	39·62	·38	37·07	11·28	74·62	−0·13
10	342 545	174·087	−0·116	39·38	·38	36 84	11·23	74·58	−0·12
12	342·469	174·320	−0·110	39·14	·37	36·62	11·17	74·54	−0·12
14	342·390	174·563	−0·104	38·91	·37	36 40	11·11	74·49	−0·11
16	342·308	174·817	−0·098	38·68	·36	36·19	11·03	74·44	−0·10
18	342·223	175·081	−0·091	38·46	·35	35·98	10·94	74·38	−0·10
20	342·136	175·354	−0·084	38·24	·34	35·77	10·85	74·32	−0·09
22	342·046	175·636	−0·076	38·02	·33	35·57	10·74	74·26	−0·08
24	341 953	175·929	−0 068	37·81	·33	35·37	10·63	74·20	−0·07
26	341·858	176·230	−0·059	37·60	·32	35·18	10·50	74·14	−0·06
28	341·761	176·539	−0·050	37·40	·31	34·99	10·37	74·08	−0·05
30	341·662	176·858	−0·041	37·20	·30	34·81	10·23	74·01	−0·04
Dec. 2	341·561	177·185	−0·032	37·01	·29	34·63	10·08	73·95	−0·03
4	341·458	177·519	−0·022	36·82	·28	34·45	9·92	73·88	−0·02
6	341·353	177·862	−0·012	36·64	·26	34·28	9·76	73·82	−0·01
8	341·247	178·212	−0·002	36·46	·25	34·11	9·58	73·75	0·00
10	341·140	178·570	+0·009	36·29	·24	33·95	9·40	73·68	+0·01
12	341·031	178·934	+0·020	36·12	·23	33·79	9·21	73·62	+0·02
14	340·921	179·306	+0·032	35·96	0·22	33·64	9·02	73·55	+0·03

Greenwich Noon. 1902.		Longitude of Ⅱ's Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A−0.	R.
		°	°	°	m	°	°
Oct.	1	307·99	229·67	−0·42	37·213		
	3	263·67	170·09	·44	37·436		
	5	219·33	110·49	·46	37·665		
	7	174·98	50·88	·47	37·898		
	9	130·61	351·25	·48	38·135	182·486	+0·136
	11	86·22	291·60	·50	38·375		
	13	41·81	231·93	·51	38·616		
	15	357·39	172·25	·52	38·864		
	17	312·97	112·58	·53	39·114		
	19	268·53	52·88	·54	39·364	183·367	+0·183
	21	224·08	353·17	·55	39·617		
	23	179·61	293·45	·55	39·870		
	25	135·12	233·70	·55	40·125		
	27	90·61	173·94	·56	40·382		
	29	46·10	114·16	·56	40·639	184·249	+0·230
	31	1·58	54·38	·56	40·897		
Nov.	2	317·05	354·59	·56	41·155		
	4	272·50	294·78	·56	41·413		
	6	227·94	234·96	·56	41·671		
	8	183·37	175·13	·55	41·928	185·131	+0·275
	10	138·79	115·29	·55	42·185		
	12	94·20	55·44	·54	42·440		
	14	49·60	355·58	·54	42·694		
	16	4·99	295·72	·53	42·947		
	18	320·38	235·85	·52	43·198	186·014	+0·322
	20	275·76	175·97	·51	43·447		
	22	231·12	116·07	·50	43·693		
	24	186·48	56·17	·49	43·939		
	26	141·83	356·26	·48	44·180		
	28	97·18	296·35	·47	44·419	186·898	+0·370
	30	52·52	236·43	·46	44·654		
Dec.	2	7·85	176·50	·44	44·887		
	4	323·17	116·57	·43	45·116		
	6	278·49	56·63	·41	45·342		
	8	233·81	356·69	·40	45·564	187·784	+0·417
	10	189·12	296·74	·38	45·781		
	12	144·42	236·79	·37	45·995		
	14	99·72	176·83	−0·35	46·205		

Greenwich Noon.	P.	L−O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1902.	°	°	°	″	″	″	″	°	°
Dec. 16	340·810	179·683	+0·044	35·80	0·21	33·49	8·82	73·48	+0·05
18	340·697	180·068	+0·056	35·64	·20	33·35	8·61	73·41	+0·06
20	340·584	180·458	+0·069	35·49	·19	33·21	8·40	73·35	+0·07
22	340·470	180·855	+0·082	35·35	·18	33·07	8·18	73·28	+0·09
24	340·356	181·257	+0·096	35·21	·17	32·94	7·96	73·22	+0·10
26	340·242	181·665	+0·110	35·08	·16	32·82	7·73	73·16	+0·12
28	340·127	182·079	+0·125	34·95	·15	32·70	7·49	73·10	+0·13
30	340·012	182·497	+0·140	34·82	·14	32·58	7·25	73·05	+0·15
1903.									
Jan. 1	339·897	182·921	+0·155	34·70	·13	32·47	7·00	73·01	+0·17
3	339·781	183·350	+0·170	34·59	·12	32·36	6·75	72·96	+0·18
5	339·665	183·781	+0·186	34·48	·11	32·26	6·50	72·92	+0·20
7	339·550	184·219	+0·202	34·38	·10	32·16	6·24	72·87	+0·22
9	339·435	184·659	+0·219	34·28	·09	32·07	5·98	72·83	+0·23
11	339·319	185·104	+0·236	34·19	·08	31·98	5·71	72·78	+0·25
13	339·204	185·552	+0·253	34·10	·08	31·90	5·44	72·74	+0·27
15	339·088	186·003	+0·271	34·01	·07	31·82	5·17	72·69	+0·29
17	338·972	186·459	+0·289	33·93	0·06	31·74	4·89	72·65	+0·31

The following is a list of the Greenwich Mean Times when the Zero meridians of the two adopted systems cross the centre of the illuminated disc :—

System I.

1902.	d	h	m	1902.	d	h	m	1902.	d	h	m	1902.	d	h	m
Feb.	21	5	10·38	Feb.	27	18	40·19	Mar.	6	8	9·86	Mar.	12	21	39·39
	15	1·00			28	4	30·80			18	0·46		13	7	29·98
	22	0	51·62			14	21·41		7	3	51·06			17	20·57
		10	42·24	Mar.	1	0	12·02			13	41·66		14	3	11·17
		20	32·85			10	2·63			23	32·26			13	1·76
	23	6	23·47			19	53·24		8	9	22·86			22	52·35
		16	14·08		2	5	43·85			19	13·45		15	8	42·94
	24	2	4·69			15	34·45		9	5	4·05			18	33·53
		11	55·30		3	1	25·05			14	54·64		16	4	24·12
		21	45·91			11	15·66		10	0	45·23			14	14·71
	25	7	36·52			21	6·26			10	35·83		17	0	5·30
		17	27·13		4	6	56·86			20	26·43			9	55·89
	26	3	17·74			16	47·46		11	6	17·02			19	46·47
		13	8·35		5	2	38·06			16	7·61		18	5	37·05
		22	58·97			12	28·66		12	1	58·21			15	27·63
	27	8	49·58			22	19·26			11	48·80		19	1	18·21

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 L.	870°·27 II.	Corr. for Phase.	Light-time.	A−O.	B.
1902.	°	°	°	m	″	″
Dec. 16	55·02	116·87	−0·34	46·410		
18	10·31	56·90	·32	46·610	188·671	+0·465
20	325·60	356·93	·31	46·804		
22	280·89	296·96	·29	46·995		
24	236·18	236·99	·28	47·180		
26	191·46	177·01	·26	47·360		
28	146·74	117·03	·25	47·534	189·559	+0·512
30	102·02	57·05	·23	47·705		
1903.						
Jan. 1	57·30	357·06	·21	47·868		
3	12·57	297·08	·20	48·026		
5	327·84	237·09	·18	48·178		
7	283·12	177·11	·17	48·324	190·448	+0·559
9	238·40	117·12	·16	48·464		
11	193·67	57·14	·14	48·598		
13	148·95	357·15	·13	48·726		
15	104·22	297·17	·12	48·848		
17	59·49	237·19	−0·10	48·963	191·338	+0·607

System I.

1902.	d	h	m	1902.	d	h	m	1902.	d	h	m	1902.	d	h	m
Mar.	19	11	8·79	Mar.	26	20	19·17	Apr.	3	5	29·35	Apr.	10	14	39·33
		20	59·37		27	6	9·74			15	19·91		11	0	29·88
	20	6	49·96			16	0·31		4	1	10·47			10	20·42
		16	40·54		28	1	50·88			11	1·03			20	10·96
	21	2	31·12			11	41·45			20	51·60		12	6	1·51
		12	21·70			21	32·03		5	6	42·16			15	52·06
		22	12·28		29	7	22·59			16	32·72		13	1	42·60
	22	8	2·86			17	13·15		6	2	23·29			11	33·14
		17	53·44		30	3	3·72			12	13·85			21	23·68
	23	3	44·01			12	54·28			22	4·42		14	7	14·23
		13	34·59			22	44·84		7	7	54·98			17	4·77
		23	25·16		31	8	35·40			17	45·53		15	2	55·31
	24	9	15·73			18	25·96		8	3	36·07			12	45·85
		19	6·31	Apr.	1	4	16·53			13	26·62			22	36·40
	25	4	56·88			14	7·09			23	17·16		16	8	26·94
		14	47·45			23	57·65		9	9	7·70			18	17·48
	26	0	38·02		2	9	48·22			18	58·25		17	4	8·02
		10	28·60			19	38·78		10	4	48·79			13	58·56

System I.

1902.	d	h	m	1902.	d	h	m	1902.	d	h	m	1902.	d	h	m
Apr.	17	23	49·09	May	3	13	49·01	May	19	3	47·96	June	3	17	45·95
	18	9	39·62			23	39·52			13	38·44		4	3	36·41
		19	30·16		4	9	30·03			23	28·93			13	26·87
	19	5	20·69			19	20·54		20	9	19·41			23	17·33
		15	11·22		5	5	11·05			19	9·89		5	9	7·79
	20	1	1·75			15	1·56		21	5	0·37			18	58·25
		10	52·29		6	0	52·07			14	50·85		6	4	48·70
		20	42·82			10	42·58		22	0	41·33			14	39·15
	21	6	33·35			20	33·09			10	31·81		7	0	29·60
		16	23·88		7	6	23·60			20	22·29			10	20·05
	22	2	14·41			16	14·11		23	6	12·77			20	10·50
		12	4·94		8	2	4·61			16	3·24		8	6	0·95
		21	55·47			11	55·11		24	1	53·72			15	51·40
	23	7	46·01			21	45·61			11	44·20		9	1	41·85
		17	36·54		9	7	36·11			21	34·68			11	32·30
	24	3	27·07			17	26·61		25	7	25·15			21	22·75
		13	17·60		10	3	17·11			17	15·63		10	7	13·20
		23	8·14			13	7·61		26	3	6·11			17	3·65
	25	8	58 67			22	58·11			12	56·59		11	2	54·10
		18	49·20		11	8	48·61			22	47·07			12	44·55
	26	4	39·73			18	39·11		27	8	37·54			22	35·00
		14	30·26		12	4	29·61			18	28·01		12	8	25·45
	27	0	20·79			14	20·11		28	4	18·48			18	15·90
		10	11·32		13	0	10·61			14	8·95		13	4	6·35
		20	1·84			10	1·10			23	59·42			13	56·80
	28	5	52·35			19	51·60		29	9	49·89			23	47·25
		15	42·86		14	5	42·09			19	40·35		14	9	37·70
	29	1	33·37			15	32·59		30	5	30·82			19	28·15
		11	23·89		15	1	23·07			15	21·29		15	5	18·59
		21	14·40			11	13·56		31	1	11·76			15	9·03
	30	7	4·91			21	4·05			11	2·22		16	0	59·47
		16	55·42		16	6	54·54			20	52·69			10	49·91
May	1	2	45·94			16	45·04	June	1	6	43·16			20	40·35
		12	36·45		17	2	35·54			16	33·63		17	6	30·79
		22	26·96			12	26·04		2	2	24·10			16	21·23
	2	8	17·47			22	16·52			12	14·57		18	2	11·67
		18	7·98		18	8	7·01			22	5·03			12	2·11
	3	3	58·50			17	57·49		3	7	55·49			21	52·55

System I.

1902.	d	h	m	1902.	d	h	m	1902.	d	h	m	1902.	d	h	m
June	19	7	42·99	July	4	21	39·17	July	20	11	34·82	Aug.	5	1	30·35
		17	33·42		5	7	29·59			21	25·23			11	20·76
	20	3	23·85			17	20·01		21	7	15·64			21	11·17
		13	14·28		6	3	10·42			17	6·05		6	7	1·59
		23	4·72			13	0·84		22	2	56·46			16	52·00
	21	8	55·15			22	51·25			12	46·87		7	2	42·41
		18	45·58		7	8	41·67			22	37·28			12	32·83
	22	4	36·01			18	32·08		23	8	27·69			22	23·24
		14	26·44		8	4	22·50			18	18·10		8	8	13·66
	23	0	16 87			14	12·91		24	4	8·51			18	4·07
		10	7·30		9	0	3·33			13	58·92		9	3	54·49
		19	57·73			9	53·74			23	49·33			13	44·91
	24	5	48·16			19	44·16		25	9	39·74			23	35·33
		15	38·59		10	5	34·57			19	30·14		10	9	25·75
	25	1	29·02			15	24·98		26	5	20·54			19	16·17
		11	19·45		11	1	15·39			15	10·94		11	5	6·59
		21	9·88			11	5 80		27	1	1·34			14	57·01
	26	7	0·31			20	56·21			10	51·74		12	0	47·43
		16	50·74		12	6	46·62			20	42·15			10	37·86
	27	2	41·17			16	37·03		28	6	32·56			20	28·28
		12	31·60		13	2	27·44			16	22·97		13	6	18·70
		22	22·03			12	17·85		29	2	13·38			16	9·13
	28	8	12·45			22	8·26			12	3·79		14	1	59·55
		18	2·87		14	7	58·67			21	54·20			11	49·97
	29	3	53·29			17	49·08		30	7	44·61			21	40·40
		13	43·71		15	3	39·49			17	35·02		15	7	30·82
		23	34·13			13	29·90		31	3	25·43			17	21·25
	30	9	24·55			23	20·31			13	15·84		16	3	11·68
		19	14·97		16	9	10·72			23	6·25			13	2·11
July	1	5	5·39			19	1·13	Aug.	1	8	56·66			22	52·54
		14	55·81		17	4	51·54			18	47·07		17	8	42·97
	2	0	46·23			14	41·95		2	4	37·48			18	33·40
		10	36·65		18	0	32·36			14	27·89		18	4	23·84
		20	27·07			10	22·77		3	0	18·30			14	14·27
	3	6	17·49			20	13·18			10	8·71		19	σ	4·71
		16	7·91		19	6	3·59			19	59·12			9	55·14
	4	1	58·33			15	54·00		4	5	49·53			19	45·58
		11	48·75		20	1	44·41			15	39·94		20	5	36·02

System I.

1902.	d	h	m	1902.	d	h	m	1902.	d	h	m	1902.	d	h	m
Aug.	20	15	26·46	Sept.	5	5	23·84	Sept.	20	19	22·71	Oct.	6	9	23·16
	21	1	16·90			15	14·32		21	5	13·23			19	13·72
		11	7·34		6	1	4·80			15	3·75		7	5	4·28
		20	57·78			10	55·28		22	0	54·28			14	54·84
	22	6	48·23			20	45·76			10	44·80		8	0	45·40
		16	38·67		7	6	36·24			20	35·32			10	35·96
	23	2	29·11			16	26·72		23	6	25·85			20	26·52
		12	19·56		8	2	17·20			16	16·37		9	6	17·09
		22	10·00			12	7·68		24	2	6·89			16	7·66
	24	8	0·45			21	58·16			11	57·42		10	1	58·23
		17	50·89		9	7	48·65			21	47·95			11	48·80
	25	3	41·34			17	39·14		25	7	38·48			21	39·37
		13	31·79		10	3	29·63			17	29·01		11	7	29·94
		23	22·24			13	20·13		26	3	19·55			17	20·52
	26	9	12·69			23	10·62			13	10·08		12	3	11·09
		19	3·15		11	9	1·11			23	0·61			13	1·66
	27	4	53·60			18	51·61		27	8	51·15			22	52·23
		14	44·06		12	4	42·10			18	41·69		13	8	42·81
	28	0	34·51			14	32·60		28	4	32·22			18	33·38
		10	24·97		13	0	23·09			14	22·76		14	4	23·96
		20	15·43			10	13·59		29	0	13·30			14	14·53
	29	6	5·89			20	4·09			10	3·84		15	0	5·11
		15	56·35		14	5	54·59			19	54·38			9	55·69
	30	1	46·81			15	45·09		30	5	44·93			19	46·27
		11	37·27		15	1	35·59			15	35·47		16	5	36·85
		21	27·74			11	26·09	Oct.	1	1	26·02			15	27·43
	31	7	18·20			21	16·60			11	16·56		17	1	18·02
		17	8·67		16	7	7·10			21	7·11			11	8·60
Sept.	1	2	59·13			16	57·60		2	6	57·65			20	59·18
		12	49·60		17	2	48·10			16	48·19		18	6	49·77
		22	40·06			12	38·61		3	2	38·74			16	40·35
	2	8	30·53			22	29·12			12	29·29		19	2	30·94
		18	21·00		18	8	19·63			22	19·84			12	21·53
	3	4	11·47			18	10·14		4	8	10·39			22	12·12
		14	1 94		19	4	0·65			18	0·94		20	8	2·71
		23	52·42			13	51·16		5	3	51·50			17	53·31
	4	9	42·89			23	41·67			13	42·05		21	3	43·90
		19	33·37		20	9	32·19			23	32·60			13	34·49

System I.

1902.	d	h	m
Oct.	21	23	25·08
	22	9	15·68
		19	6·27
	23	4	56·86
		14	47·46
	24	0	38·06
		10	28·66
		20	19·26
	25	6	9·86
		16	0·47
	26	1	51·07
		11	41·68
		21	32·28
	27	7	22·88
		17	13·48
	28	3	4·09
		12	54·69
		22	45·29
	29	8	35·90
		18	26·51
	30	4	17·12
		14	7·73
		23	58·34
	31	9	48·96
		19	39·57
Nov.	1	5	30·18
		15	20·79
	2	1	11·41
		11	2·02
		20	52·64
	3	6	43·25
		16	33·86
	4	2	24·48
		12	15·09
		22	5·71
	5	7	56·33
		17	46·95
		3	37·57

1902.	d	h	m
Nov.	6	13	28·19
		23	18·81
	7	9	9·43
		19	0·05
	8	4	50·68
		14	41·31
	9	0	31·94
		10	22·57
		20	13·20
	10	6	3·83
		15	54·46
	11	1	45·09
		11	35·72
		21	26·35
	12	7	16·99
		17	7·62
	13	2	58·25
		12	48·88
		22	39·51
	14	8	30·14
		18	20·78
	15	4	11·41
		14	2·05
		23	52·68
	16	9	43·32
		19	33·95
	17	5	24·58
		15	15·22
	18	1	5·86
		10	56·50
		20	47·14
	19	6	37·78
		16	28·42
	20	2	19·07
		12	9·71
		22	0·35
	21	7	50·99
		17	41·64

1902.	d	h	m
Nov.	22	3	32·28
		13	22·92
		23	13·57
	23	9	4·21
		18	54·85
	24	4	45·50
		14	36·14
	25	0	26·79
		10	17·44
		20	8·09
	26	5	58·73
		15	49·38
	27	1	40·03
		11	30·68
		21	21·33
	28	7	11·98
		17	2·63
	29	2	53·28
		12	43·94
		22	34·59
	30	8	25·24
		18	15·90
Dec.	1	4	6·55
		13	57·20
		23	47·86
	2	9	38·51
		19	29·17
	3	5	19·82
		15	10·48
	4	1	1·13
		10	51·79
		20	42·45
	5	6	33·10
		16	23·76
	6	2	14·41
		12	5·07
		21	55·73
	7	7	46·38

1902.	d	h	m
Dec.	7	17	37·04
	8	3	27·70
		13	18·36
		23	9·02
	9	8	59·68
		18	50·34
	10	4	41·00
		14	31·66
	11	0	22·32
		10	12·99
		20	3·65
	12	5	54·31
		15	44·98
	13	1	35·64
		11	26·30
		21	16·97
	14	7	7·63
		16	58·29
	15	2	48·96
		12	39·62
		22	30·29
	16	8	20·95
		18	11·62
	17	4	2·28
		13	52·95
		23	43·61
	18	9	34·28
		19	24·94
	19	5	15·61
		15	6·27
	20	0	56·94
		10	47·60
		20	38·27
	21	6	28·93
		16	19·60
	22	2	10·27
		12	0·94
		21	51·60

System I.

1902.	d	h	m
Dec.	23	7	42·27
		17	32·94
	24	3	23·61
		13	14·28
		23	4·95
	25	8	55·62
		18	46·29
	26	4	36·96
		14	27·63
	27	0	18·30
		10	8·97
		19	59·64
	28	5	50·31
		15	40·98
	29	1	31·65
		11	22·32

1902.	d	h	m
Dec.	29	21	12·99
	30	7	3·66
		16	54·33
	31	2	45·00
		12	35·67
		22	26·34
1903.			
Jan.	1	8	17·01
		18	7·68
	2	3	58·35
		13	49·03
		23	39·70
	3	9	30·37
		19	21·04
	4	5	11·71
		15	2·39

1903.	d	h	m
Jan.	5	0	53·06
		10	43·73
		20	34·40
	6	6	25·07
		16	15·74
	7	2	6·42
		11	57·09
		21	47·76
	8	7	38·43
		17	29·10
	9	3	19·78
		13	10·45
		23	1·12
	10	8	51·79
		18	42·46
	11	4	33·14

1903.	d	h	m
Jan.	11	14	23·81
	12	0	14·48
		10	5·16
		19	55·83
	13	5	46·50
		15	37·18
	14	1	27·85
		11	18·52
		21	9·19
	15	6	59·87
		16	50·54
	16	2	41·21
		12	31·89
		22	22·56
	17	8	13·23

System II.

1902.	d	h	m
Feb.	21	0	22·48
		10	18·27
		20	14·07
	22	6	9·86
		16	5·65
	23	2	1·44
		11	57·24
		21	53·03
	24	7	48·82
		17	44·61
	25	3	40·40
		13	36·19
		23	31·98
	26	9	27·77
		19	23·56
	27	5	19·35
		15	15·14
	28	1	10·93
		11	6·72
		21	2·51

1902.	d	h	m
Mar.	1	6	58·30
		16	54·09
	2	2	49·88
		12	45·67
		22	41·46
	3	8	37·24
		18	33·02
	4	4	28·80
		14	24·58
	5	0	20·36
		10	16·14
		20	11·91
	6	6	7·69
		16	3·47
	7	1	59·25
		11	55·02
		21	50·80
	8	7	46·58
		17	42·36
	9	3	38·13

1902.	d	h	m
Mar.	9	13	33·91
		23	29·69
	10	9	25·46
		19	21·24
	11	5	17·01
		15	12·79
	12	1	8·56
		11	4·33
		21	0·10
	13	6	55·87
		16	51·64
	14	2	47·41
		12	43·17
		22	38·94
	15	8	34·70
		18	30·47
	16	4	26·23
		14	22·00
	17	0	17·76
		10	13·53

1902.	d	h	m
Mar.	17	20	9·29
	18	6	5·06
		16	0·82
	19	1	56·58
		11	52·34
		21	48·10
	20	7	43·86
		17	39·62
	21	3	35·38
		13	31·14
		23	26·90
	22	9	22·66
		19	18·42
	23	5	14·18
		15	9·93
	24	1	5·68
		11	1·43
		20	57·18
	25	6	52·93
		16	48·68

System II.

1902.	d	h	m
Mar.	26	2	44·43
		12	40·17
		22	35·92
	27	8	31·67
		18	27·42
	28	4	23·17
		14	18·91
	29	0	14·66
		10	10·41
		20	6·16
	30	6	1·90
		15	57·65
	31	1	53·39
		11	49·14
		21	44·88
Apr.	1	7	40·63
		17	36·38
	2	3	32·12
		13	27·86
		23	23·60
	3	9	19·33
		19	15·07
	4	5	10·80
		15	6·54
	5	1	2·27
		10	58·01
		20	53·74
	6	6	49·48
		16	45·21
	7	2	40·95
		12	36·68
		22	32·42
	8	8	28·15
		18	23·89
	9	4	19·62
		14	15·35
	10	0	11·08
		10	6·80

1902.	d	h	m
Apr.	10	20	2·53
	11	5	58 26
		15	53·99
	12	1	49·71
		11	45·43
		21	41·15
	13	7	36·87
		17	32·58
	14	3	28·30
		13	24·02
		23	19·74
	15	9	15·45
		19	11·17
	16	5	6·88
		15	2·60
	17	0	58·32
		10	54·03
		20	49·75
	18	6	45·46
		16	41·18
	19	2	36·89
		12	32·61
		22	28·32
	20	8	24·03
		18	19·75
	21	4	15·46
		14	11·17
	22	0	6·88
		10	2·59
		19	58·29
	23	5	54·00
		15	49·70
	24	1	45·41
		11	41·11
		21	36·82
	25	7	32 52
		17	28·23
	26	3	23·93

1902.	d	h	m
Apr.	26	13	19·63
		23	15·33
	27	9	11·03
		19	6·73
	28	5	2·43
		14	58·13
	29	0	53·83
		10	49·53
		20	45·23
	30	6	40·93
		16	36·62
May	1	2	32·32
		12	28·01
		22	23·71
	2	8	19·40
		18	15·09
	3	4	10·78
		14	6·47
	4	0	2·15
		9	57·84
		19	53·53
	5	5	49·21
		15	44·89
	6	1	40·58
		11	36·26
		21	31·95
	7	7	27·63
		17	23·32
	8	3	19 00
		13	14·69
		23	10·38
	9	9	6·07
		19	1·75
	10	4	57·43
		14	53·11
	11	0	48·79
		10	44·46
		20	40·14

1902.	d	h	m
May	12	6	35·81
		16	31·48
	13	2	27·15
		12	22·82
		22	18·48
	14	8	14·15
		18	9·82
	15	4	5·48
		14	1·15
		23	56·82
	16	9	52·48
		19	48·15
	17	5	43·82
		15	39·48
	18	1	35·15
		11	30·82
		21	26·48
	19	7	22·15
		17	17·81
	20	3	13·48
		13	9·14
		23	4·80
	21	9	0·47
		18	56·13
	22	4	51·79
		14	47·45
	23	0	43·10
		10	38 76
		20	34·41
	24	6	30·07
		16	25·72
	25	2	21·38
		12	17·03
		22	12·68
	26	8	8·33
		18	3·98
	27	3	59·63
		13	55·28

System II.

1902.	d	h	m
May	27	23	50·93
	28	9	46·58
		19	42·22
	29	5	37·87
		15	33·51
	30	1	29·16
		11	24·80
		21	20·45
	31	7	16·09
		17	11·74
June	1	3	7·38
		13	3·02
		22	58·66
	2	8	54·30
		18	49·93
	3	4	45·57
		14	41·21
	4	0	36·84
		10	32·48
		20	28·11
	5	6	23·75
		16	19·38
	6	2	15·02
		12	10·65
		22	6·29
	7	8	1·92
		17	57·55
	8	3	53·18
		13	48·81
		23	44·44
	9	9	40·07
		19	35·70
	10	5	31·33
		15	26·96
	11	1	22·59
		11	18·21
		21	13·84
	12	7	9·46

1902.	d	h	m
June	12	17	5·08
	13	3	0·70
		12	56·32
		22	51·94
	14	8	47 56
		18	43·18
	15	4	38·80
		14	34·42
	16	0	30·04
		10	25·66
		20	21·27
	17	6	16·89
		16	12·50
	18	2	8·12
		12	3·73
		21	59 35
	19	7	54·96
		17	50·58
	20	3	46·19
		13	41·81
		23	37·42
	21	9	33·03
		19	28 64
	22	5	24·25
		15	19·86
	23	1	15·46
		11	11·07
		21	6·68
	24	7	2·28
		16	57·88
	25	2	53·49
		12	49·10
		22	44·71
	26	8	40·31
		18	35·91
	27	4	31·51
		14	27·11
	28	0	22·71

1902.	d	h	m
June	28	10	18·31
		20	13·91
	29	6	9·51
		16	5·11
	30	2	0·71
		11	56·31
		21	51 91
July	1	7	47·51
		17	43·11
	2	3	38·70
		13	34·30
		23	29 89
	3	9	25 49
		19	21·08
	4	5	16·68
		15	12·27
	5	1	7·87
		11	3·46
		20	59·06
	6	6	54·65
		16	50·24
	7	2	45·84
		12	41·43
		22	37·02
	8	8	32·61
		18	28·20
	9	4	23·79
		14	19·38
	10	0	14·97
		10	10·56
		20	6·15
	11	6	1·74
		15	57·33
	12	1	52·92
		11	48·51
		21	44·10
	13	7	39·68
		17	35·27

1902.	d	h	m
July	14	3	30·86
		13	26·44
		23	22·03
	15	9	17·61
		19	13·20
	16	5	8·78
		15	4·37
	17	0	59·95
		10	55 54
		20	51·12
	18	6	46·71
		16	42·29
	19	2	37·88
		12	33·46
		22	29·05
	20	8	24 63
		18	20·21
	21	4	15·79
		14	11·37
	22	0	6 95
		10	2·54
		19	58·12
	23	5	53·70
		15	49·29
	24	1	44·87
		11	40·45
		21	36·04
	25	7	31 62
		17	27·20
	26	3	22·79
		13	18·37
		23	13·95
	27	9	9·54
		19	5·12
	28	5	0·70
		14	56·29
	29	0	51·87
		10	47·45

System II.

1902.	d	h	m	1902.	d	h	m	1902.	d	h	m	1902.	d	h	m
July	29	20	43·04	Aug.	14	13	55·53	Aug.	30	7	9·02	Sept.	15	0	24·02
	30	6	38·62			23	51·13			17	4·66			10	19·70
		16	34·20		15	9	46·74		31	3	0·30			20	15·38
	31	2	29·79			19	42·34			12	55·95		16	6	11·07
		12	25·37		16	5	37·94			22	51·59			16	6·75
		22	20·95			15	33·54	Sept.	1	8	47·24		17	2	2·44
Aug.	1	8	16·54		17	1	29·14			18	42·88			11	58·12
		18	12·12			11	24·75		2	4	38·53			21	53 81
	2	4	7·70			21	20·35			14	34·17		18	7	49·49
		14	3·29		18	7	15·95		3	0	29·82			17	45·18
		23	58·87			17	11·55			10	25·46		19	3	40 87
	3	9	54·46		19	3	7·16			20	21·11			13	36·56
		19	50·05			13	2·78		4	6	16·75			23	32·25
	4	5	45·63			22	58·39			16	12·41		20	9	27·95
		15	41·22		20	8	54·01		5	2	8·06			19	23·64
	5	1	36·81			18	49·63			12	3·72		21	5	19 34
		11	32·39		21	4	45 25			21	59·37			15	15·04
		21	27·98			14	40·87		6	7	55·03		22	1	10·73
	6	7	23·57		22	0	36·49			17	50·68			11	6·43
		17	19·16			10	32·12		7	3	46·34			21	2·13
	7	3	14·75			20	27·74			13	41·99		23	6	57·83
	7	13	10·34		23	6	23·37			23	37·65			16	53·52
		23	5·93			16	18·99		8	9	33·30		24	2	49·22
	8	9	1·53		24	2	14·61			19	28·96			12	44·93
		18	57·12			12	10·24		9	5	24·62			22	40 64
	9	4	52·72			22	5·86			15	20·28		25	8	36·35
		14	48·31		25	8	1·48		10	1	15·95			18	32·06
	10	0	43·91			17	57·11			11	11·61		26	4	27·77
		10	39·51		26	3	52·73			21	7 28			14	23·48
		20	35·11			13	48·35		11	7	2·95		27	0	19·19
	11	6	30·71			23	43·98			16	58·62			10	14·91
		16	26·32		27	9	39·60		12	2	54·30			20	10·62
	12	2	21·92			19	35·23			12	49·97		28	6	6·33
		12	17·52		28	5	30·85			22	45·65			16	2·05
		22	13·12			15	26·48		13	8	41·32		29	1	57·77
	13	8	8·73		29	1	22·11			18	37·00			11	53 49
		18	4·33			11	17·75		14	4	32·67			21	49·21
	14	3	59·93			21	13·38			14	28·35		30	7	44·93

System II.

1902.	d	h	m	1902.	d	h	m	1902.	d	h	m	1902.	d	h	m
Sept.	30	17	40·66	Oct.	16	10	58·83	Nov.	1	4	18·32	Nov.	16	21	38·89
Oct.	1	3	36·38			20	54·59			14	14·11		17	7	34·70
		13	32·10		17	6	50·34		2	0	9·90			17	30·51
		23	27·83			16	46·10			10	5·70		18	3	26·33
	2	9	23·54		18	2	41·86			20	1·49			13	22·15
		19	19·26			12	37·62		3	5	57·28			23	17·97
	3	5	14·99			22	33·38			15	53·07		19	9	13·79
		15	10·71		19	8	29·15		4	1	48·87			19	9·62
	4	1	6·43			18	24·92			11	44·66		20	5	5·44
		11	2·16		20	4	20·69			21	40·46			15	1·26
		20	57·89			14	16·46		5	7	36·25		21	0	57·08
	5	6	53·63		21	0	12·24			17	32·05			10	52·91
		16	49·36			10	8·01		6	3	27·85			20	48·73
	6	2	45·09			20	3·78			13	23·65		22	6	44·55
		12	40·83		22	5	59·56			23	19·45			16	40·38
		22	36·56			15	55·33		7	9	15·26		23	2	36·20
	7	8	32·30		23	1	51·11			19	11·06			12	32·03
		18	28·04			11	46·88		8	5	6·87			22	27·85
	8	4	23·78			21	42·65			15	2·67		24	8	23·6
		14	19·52		24	7	38·43		9	0	58·48			18	19·50
	9	0	15·27			17	34·20			10	54·29		25	4	15·32
		10	11·02		25	3	29·98			20	50·10			14	11·15
		20	6·77			13	25·75		10	6	45·91		26	0	6·98
	10	6	2·52			23	21·53			16	41·72			10	2·81
		15	58·27		26	9	17·31		11	2	37·53			19	58·63
	11	1	54·03			19	13·08			12	33·34		27	5	54·46
		11	49·78		27	5	8·86			22	29·15			15	50·29
		21	45·53			15	4·64		12	8	24·96		28	1	46·12
	12	7	41·29		28	1	0·42			18	20·77			11	41·95
		17	37·04			10	56·21		13	4	16·58			21	37·78
	13	3	32·79			20	51·99			14	12·39		29	7	33·61
		13	28·55		29	6	47·78		14	0	8·20			17	29·44
		23	24·30			16	43·57			10	4·02		30	3	25·27
	14	9	20·06		30	2	39·36			19	59·83			13	21·1
		19	15·81			12	35·15		15	5	55·64			23	16·94
	15	5	11·57			22	30·95			15	51·45	Dec.	1	9	12·77
		15	7·32		31	8	26·74		16	1	47·27			19	8·61
	16	1	3·08			18	22·53			11	43·08		2	5	4·44

System II.

1902.	d	h	m	1902.	d	h	m	1902.	d	h	m	1903.	d	h	m
Dec.	2	15	0·28	Dec.	14	5	3·77	Dec.	25	19	7·46	Jan.	5	23	15·43
	3	0	56·11			14	59·61		26	5	3·31		6	9	11·28
		10	51·95		15	0	55·45			14	59·16			19	7·13
		20	47·78			10	51·29		27	0	55·01		7	5	2·99
	4	6	43·61			20	47·13			10	50·86			14	58·84
		16	39·45		16	6	42·98			20	46·71		8	0	54·69
	5	2	35·28			16	38·82		28	6	42·56			10	50·54
		12	31·12		17	2	34·67			16	38·41			20	46·39
		22	26·95			12	30·51		29	2	34·26		9	6	42·24
	6	8	22·79			22	26·35			12	30·11			16	38·10
		18	18·63		18	8	22·20			22	25·96		10	2	33·95
	7	4	14·46			18	18·04		30	8	21·81			12	29·80
		14	10·30		19	4	13·89			18	17·66			22	25·65
	8	0	6·14			14	9·74		31	4	13·51		11	8	21·50
		10	1·98		20	0	5·58			14	9·37			18	17·36
		19	57·82			10	1·43	1903.					12	4	13·21
	9	5	53·66			19	57·28	Jan.	1	0	5·22			14	9·06
		15	49·50		21	5	53·12			10	1·07		13	0	4·91
	10	1	45·35			15	48·97			19	56·92			10	0·76
		11	41·19		22	1	44·82		2	5	52·77			19	56·61
		21	37·03			11	40·67			15	48·62		14	5	52·46
	11	7	32·87			21	36·52		3	1	44·47			15	48·32
		17	28·71		23	7	32·36			11	40·32		15	1	44·17
	12	3	24·56			17	28·21			21	36·17			11	40·02
		13	20·40		24	3	24·06		4	7	32·02			21	35·87
		23	16·24			13	19·91			17	27·88		16	7	31·72
	13	9	12·08			23	15·76		5	3	23·73			17	27·68
		19	7·92		25	9	11·61			13	19·58		17	3	23·43

The quantities in the ephemeris are to be interpolated directly for the times for which they are required, the equation of light having been already applied.

The position of *Jupiter's* North Pole is assumed to be R.A. $17^h\ 51^m\ 59^s{\cdot}49$, N.P.D. 25° 26′ 25″·3 at the beginning of 1902, and R.A. $17^h\ 51^m\ 59^s{\cdot}75$, N.P.D. 25° 26′ 26″·0 at the beginning of 1903.

P denotes the position-angle of the northern extremity of *Jupiter's* axis, reckoned eastward from the northernmost point of the disc.

L − O + 180°, Λ − O + 180° are the jovicentric right ascensions of the Earth and Sun respectively, reckoned in the plane of the

planet's equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere; B, *B* are the jovicentric declinations of the Earth and Sun above the planet's equator.

The adopted values of the diameters at distance 5·20 are: Equatorial 38″·419; Polar 35″·945. The sources from which these values are derived were given last year.

The assumed time for light to traverse the unit distance is 498ˢ·92, this being the same value as that used by Mr. Marth.

d denotes the jovicentric angle between the Earth and Sun.

Q denotes the position-angle of the point of greatest phase, and is reckoned eastward from the northernmost point of the disc. It also gives the position-angle of the shadows of the satellites measured from the satellites themselves.

B′ is obtained from B by the formula $\tan B' = \sec \epsilon_0 \tan B$, where $\sec \epsilon_0 = \frac{a}{b} = \frac{15{\cdot}53}{14{\cdot}53}$. Since B, B′ can never exceed some 3°, we may take the tangents as proportional to the angles. Hence it suffices in practice to find B′ by the formula $B' = \frac{15{\cdot}53}{14{\cdot}53} B$. B′ is the eccentric angle of the centre of the disc. If we call B″ the jovigraphical latitude of the centre of the disc, then we can find B″ by the formulæ:

$$\tan B' = \sec^2 \epsilon_0 \tan B \quad \text{or} \quad \tan B'' = \sec \epsilon_0 \tan B'.$$

The longitudes of *Jupiter's* central meridian are computed with unaltered values of the rates of rotation and of the zero-meridians in the two adopted systems. The addition of the "Corr. for Phase" gives the longitudes of the meridians which bisect the illuminated disc.

The sidereal periods of rotation corresponding to the two adopted systems are $9^h\ 50^m\ 30^s{\cdot}004$, $9^h\ 55^m\ 40^s{\cdot}632$.

Contrary to expectation, the longitude of the Red Spot seems to have remained nearly stationary during the last apparition. I have received the following determinations of its longitude relative to the zero-meridian of System II.

(D.=W. F. Denning, A.=E. M. Antoniadi, P.=Rev. T. E. R. Phillips.)

Date. 1901	Obs.	Long. °	Date. 1901	Obs.	Long. °	Date. 1901	Obs.	Long. °
Feb. 13	D.	43·5	June 22	A.	43 (uncertain)	July 8	D.	45·2
May 1	„	46·4	24	D.	44·7	28	„	46·54
23	„	43·6	26	A.	47·2	Aug. 21	P.	46·4
28	„	45·9	26	D.	47·1	Sept. 24	„	46·3
June 14	„	45·9	July 4	„	44·6	...	...	...

These figures show that its longitude has scarcely varied since 1900 October, when it was estimated by A. to be 45°.

A. reports a remarkable swelling of the south Tropical Belt

on September 30, making the Belt nearly touch the south Temperate Band. The longitude of this swelling (System II.) was about 194°.

Observers are reminded that the Jovian system will be presented edgewise in 1902, and a watch should be kept for mutual occultations and eclipses of the satellites.

It will be remembered that the late Mr. Marth attached particular value to measurements of the latitudes of their shadows while crossing the disc of *Jupiter*, for the purpose of improving our knowledge of the positions of their orbit-planes.

A list of times of elongation of the fifth satellite is given in the *Connaissance des Temps* for 1902.

It may be mentioned here that the *Connaissance des Temps* for 1899 and following years gives ephemerides for the satellites of *Mars*, *Saturn*, *Uranus* and *Neptune* in the same form as those formerly contributed to the *Monthly Notices* by Mr. Marth.

Benvenue, 55 *Ulundi Road*, *Blackheath*, *S.E.*:
1901 *October* 16.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

William John Greenstreet, M.A. (Camb.), Marling School, Stroud, Gloucestershire,

was balloted for and duly elected a Fellow of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

William Ambrose Kibbler, M.B., Ashby House, 3 Manor Road, Stamford Hill, N. (proposed by the Rev. T. E. R. Phillips) ;

C. F. Sandberg, M.A. Oxon., Magdalen College School, and 6 Parks Road, Oxford (proposed by H. C. Plummer) ;

Albert Walter, Royal Alfred Observatory, Mauritius (proposed by E. W. Maunder) ; and

Edward Fawcett White, Navigation Department, Merchant Venturers' Technical College, Bristol (proposed by Captain P. Thompson).

Eighty presents were announced as having been received since the last meeting, including amongst others :—S. Newcomb, "The Stars, a Study of the Universe" (presented by the publishers).

Contribution to the History of the Reflex Zenith-Tube.

By S. C. Chandler, Assoc. R.A.S.

(*Communicated by the Astronomer Royal.*)

It may not be uninteresting to the Society to lay before them the following note concerning an instrument, notable in English astronomy, whose history has passed through various phases—in the beginning of high hope, later of grievous perplexity, finally of severe disappointment. Mr. Adams, in 1852, concluded his address of presentation of the medal to Mr. Peters with the following words : " We may hope that the beautiful reflex zenith telescope of the Astronomer Royal . . . will enable us ere long to take many firm, though long-reaching, steps into regions of space hitherto untrodden." Subsequently, however, the successive discussions of Main and Downing gave unacceptable results, as is well known, and in 1882 the observations were silently abandoned.

In the *Astronomical Journal*, No. 511, it is shown that this instrument, so far from being a failure, has provided us with an invaluable record of a phenomenon which was unsuspected at the time the observations were made, and which has within the last decade become the subject of the most active and general inquiry ; namely, the relative motions of the earth's axes of rotation and figure. There is one topic, not there touched upon, on which a few words here may not be superfluous. The object of this note is to expose directly and analytically how the anomalous parallax of γ *Draconis* and aberration were brought about.

In *Astronomical Journal*, vol. xii., p. 177, it is shown that the coefficients of the sine and cosine of the Sun's longitude,

$$Y = qu - p\pi + \eta, \quad Z = pu + q\pi + \zeta \quad . \quad . \quad (A)$$

are functions of four unknown quantities; namely, the parallax π, the correction u of the assumed aberration-constant, and the coordinates of the annual component of the motion of the pole,

$$\eta = -r_2 \sin G', \quad \zeta = -r_2 \cos G'$$

r_2 and G′ being furnished by observation, and the coefficients

$$p = \sin \epsilon \cos \delta - \cos \epsilon \sin \alpha \sin \delta, \quad q = \cos \alpha \sin \delta$$

from known quantities. For γ *Draconis* we have (1865) $p = +0{\cdot}965$, $q = -0{\cdot}022$. From *Astronomical Journal*, No. 511, p. 59, we take :

	1857–63.	1864–70.
r_2	0″·166	0″·134
G′	323°	313°

consequently	η	$+0''\cdot100$	$+0''\cdot098$
„	ζ	$-0''\cdot133$	$-0''\cdot091$

which are the values of Y and Z if u and π are zero. If, on the contrary, we ignore η and ζ, as was in effect done in the earlier attempts to get aberration and parallax, we have from (A)

$$u = \frac{q\mathrm{Y} + p\mathrm{Z}}{p^2+q^2}, \quad \pi = \frac{q\mathrm{Z} - p\mathrm{Y}}{p^2+q^2}$$

which would give, introducing the above data and the assumed aberration $20''\cdot505$,

	Aberration.	Parallax.
	"	"
1857–63	20·365	−0·100
1864–70	20·408	−0·099
Mean . .	20·386	−0·100

The values actually found by Downing, from the observations 1857–75, were

$$20''\cdot378 \quad -0''\cdot131$$

thus a satisfactory agreement with the foregoing, the differences being nominal and doubtless due to the fact that he included the observations for 1871–75, which I did not.

The above demonstration, while possibly unnecessary, is not uninteresting as showing explicitly how the former anomalous results are harmonised with the truth as now perceived. The old discussions are practically attempts to find four unknowns from two equations.

It is certainly a comfort that the perplexing enigma connected with the Reflex Zenith-Tube has finally found its answer, and that the patience of the astronomers who executed this laborious series meets at last an adequate reward of useful result. The question naturally arises in the mind whether a resumption of observations by this method, with an instrument optically capable of more easily showing γ *Draconis* in the daytime, and an earnest attention to securing a higher precision as regards accidental error of observation, would not be a worthy undertaking.

If such a resumption of the investigation under these more favourable conditions be feasible, it scarcely needs to be suggested that it ought properly to extend to all the stars passing the Greenwich zenith bright enough for reflection-observation on a dark sky. This would determine both the aberration and the latitude-variation, which is not possible with a single star. At least two groups of stars in opposite right ascension would be desirable. Assuming the limit of brightness to be $6\frac{1}{2}$ magnitude, a list of all the stars that might be embraced in such a programme is appended.

No.	Mag.	(1905·0) α h m s	δ ° ′	
1	6·0	0 19 8	+51 29·6	—
2	6·1	1 44 52	28·0	—
3	6·6	1 58 0	30·7	—
4	5·4	4 59 14	28·4	Fl. 9 Aurigæ.
5	6·6	5 39 29	29·0	—
6	6·5	5 43 23	29·2	—
7	6·6	7 26 33	31·1	—
8	6·8	10 24 18	28·8	—
9	6·0	13 59 28	25·7	—
10	2·5	17 54 24	30·0	γ Draconis.
11	6·8	18 59 59	29·6	—
12	4·0	19 27 19	31·5	ι Cygni.
13	6·4	20 32 4	31·6	—

On the Velocity of a Persei. By H. F. Newall.

The following additional observations of the velocity of *a Persei* in the line of sight were obtained before I left England to observe the eclipse of the Sun in Sumatra. They are in continuation of the observations published in an earlier note (*Monthly Notices*, vol. lxi., p. 12), and were obtained with the same instrument and measured in the same way as those before published. The values of the velocity are the means of two measurements made, one by myself, the other by my assistant, A. W. Goatcher. The result for each photograph is based on measurement of about eleven lines between λ 4260 and λ 4325, and the method of reduction is the same as that briefly described in a paper published in *Monthly Notices*, vol. lxi., p. 12.

Velocity of a Persei in the Line of Sight.

Plate Number.		Velocity relative to Earth.	Correction for Earth's Orbital velocity.	Velocity relative to Sun.
F. 139	1900 Nov. 9·35	− 2·7	+ 5·8	+3·1
F. 141	10·35	− 4·4	+ 5·4	+1·0
F. 142	13·34	− 3·7	+ 4·1	+0·4
F. 143	15·33	− 4·0	+ 3·2	−0·8
F. 145	16·33	− 6·7	+ 2·7	−4·0
F. 154	Dec. 10·25	+ 7·0	− 8·1	−1·1

Plate Number.			Velocity relative to Earth.	Correction for Earth's Orbital velocity.	Velocity relative to Sun.
F. 155		13·25	+ 7·3	− 9·4	−2·1
F. 159		17·24	+13·7	−11·0	+2·6
F. 160		19·25	+12·5	−11·9	+0·6
F. 162		21·23	+12·0	−12·7	−0·7
F. 180	1901 Feb.	12·39	+25·9	−25·8	+0·1
F. 181		13·40	+24·5	−25·9	−1·4

These results were very nearly ready for publication in February last, but the appearance of the new star in *Perseus*, and stress in connection with preparations for the eclipse expedition, which started from England on March 11, stood in the way of the necessary completion of the discussion, and to my regret it was left unfinished. Meanwhile, Professor Vogel and Professor Campbell kindly responded with great promptness to the expression that I gave in my previous note to the hope that observations of the star would be secured at other observatories; and I would here express my obligations to them. Their published results (*Sitzber. Berlin Akad.* 1901, p. 51, and *Lick Obs. Bull.* No. 4) show that no support is found either at Potsdam or at the Lick Observatory for my suggestion that the velocity varies periodically.

My later observations given above showed at once that they would not fit either of the periods, 4·2 days or 16·8 days, which I had suggested as possible.

As Professor Vogel has pointed out, I have used a linear dispersion about two and a half times that obtained in the instrument he has used for making his observations at Potsdam; it is about twice as great as that used by Professor Campbell.

While it is clear that the larger dispersion might bring to light changes that were not detected on photographs of smaller scale, it is also evident that the use of it would be attended with greater risks arising from temperature changes, &c. Every precaution has been taken to avoid risks of this kind, short of putting in an arrangement for generating heat inside the non-conducting covering which surrounds the spectroscope. The photographs were obtained with all care and afford apparently excellent material for the measurements to be made. The spectrum of *α Persei* is admirably adapted for an accurate investigation; for the lines are numerous and distinct, and in spite of an exhaustive study of the material I have at present no clue as to the cause of the discrepancies.

On a Simple Method of Accurate Surveying with an Ordinary Camera. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. Measurements of photographs have proved so accurate and convenient in astronomy that they will probably be found useful elsewhere. The present paper suggests an extension of the methods adopted for treatment of the Astrographic Chart plates to terrestrial surveying; and although not definitely astronomical, since it arises out of astronomical work, it may perhaps not unsuitably be communicated to this Society.

2. *Uses of the camera in surveying hitherto.*—Instruments designed for using the camera in terrestrial surveys have hitherto started with the theodolite as a substructure. Now the theodolite is primarily designed to measure *angles*, and I hope to show in the present paper that the use of angles is unnecessary, and only complicates the formulæ. It is not an angle itself but the tangent of an angle which arises fundamentally in the work, when a view of any kind is projected on a plane; and if we keep to plane geometry with straight lines and linear formulæ, we get much simpler formulæ; just as in astronomical work it simplifies matters to use rectilinear coordinates instead of curvilinear or angular. This has not been realised (so far as I have been able to find out) in surveying any more than it was in astronomy; indeed existing instruments for photographic surveying often contain a "scale of tangents" designed to enable the surveyor to convert the convenient linear measures with which the photograph directly furnishes him into angular measures, which are really more inconvenient but to which he has become accustomed from use of the theodolite.

When the photographs have been obtained methods of making use of them have usually been graphical; and the positions of points have been laid down by the "method of intersections." Now graphical methods are limited by practical considerations, such as size of paper; and though in many cases they may be all that is necessary, it is convenient to have a more complete method. In the present paper it is shown how accurate measurements of the plate can be used, without any troublesome calculations, to give all the required data. Thus we may state the

3. *Advantages of the present method* under two heads: (*a*) the use of linear measures and formulæ entirely, instead of angles, and (*b*) the substitution of accurate measurement of the plate for graphical methods of treating the photographs. Under head (*a*) is to be ranged the considerable practical gain of doing away with any complicated or expensive mounting, and using a camera of the ordinary pattern.

4. *Principle of the method.*—Let A be the centre of a lens forming an image on a plate GE, and let the image of a point

P fall at G. We shall suppose for the present that there is no optical distortion, *i.e.* that the images on the plate all fall truly on rays through the point A ; and the way of dealing with any deviation from this law will be considered later.

Let AE be drawn normal to the plate from the centre A. The point E, which is the foot of the normal from the lens centre on the plate, is of some importance, and will be called the plate centre. Let AE=f. It is the focal length of the lens when an infinitely distant object is in focus, and in all cases is of comparable dimensions with this focal length.

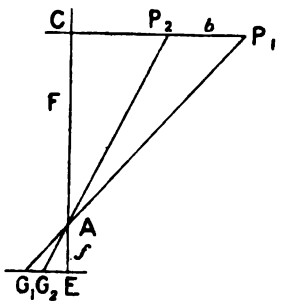


FIG. 1.

The coordinates of P in space referred to axes AC, CP are

$$AC=F \text{ say, and } CP=X$$

and if we put EG, the measured distance of the image from the plate centre, equal to x, we have of course

$$x/f=X/F \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

From measurements on a single photograph we can get nothing more than this—the ratio X/F. To determine either of these completely we must take another photograph. Now it will clearly be of advantage to keep one or other of these quantities the same in both pictures. If we keep F the same we must move along a line parallel to the plate ; if X the same, along a line perpendicular to the plate. Both these plans have special advantages, and we will consider them each in turn.

5. *The parallactic or stereoscopic method.*—Let us move the camera a measured distance b to the right, keeping it parallel to itself. (The practical method of securing these conditions will be considered presently.) Then this is equivalent to supposing all the objects in the field of view moved a distance b to the left

as in fig. 1. Denote the first and second positions by the suffixes 1 and 2; so that we have

$$\left.\begin{aligned} x_1/f &= X_1/F \\ x_2/f &= X_2/F \\ \text{and} \quad X_1 - X_2 &= b \end{aligned}\right\} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

$$\text{whence} \quad (x_1 - x_2)/f = b/F \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

$$\text{or} \quad F = \frac{bf}{x_1 - x_2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

Now bf is a constant for the pair of pictures. Thus to get the distance F of any object measured in a direction perpendicular to the plate, or the base, we measure the distances x_1 x_2 on the two plates, take their difference, and divide it into a constant.

$$\text{Again} \quad X_1 = \frac{F}{f} \cdot x_1 = \frac{b x_1}{x_1 - x_2} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

so that the other coordinate (on the ground plan) of the object is obtained equally simply. Finally if we want the elevation of the object, call its height above the horizontal plane AGE through the lens centre Y, and let y be the measured height of the image above the line EG on either picture. Then clearly

$$Y = \frac{F}{f} \cdot y = \frac{b y}{x_1 - x_2} \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

Thus the actual coordinates XYF of the object in space are obtained from the measures on the plate x, y, and the focal length f on multiplying by the factor $b/(x_1 - x_2)$. But since this may also be written in the form F/f and is constant, it follows (as might have been expected) that we can increase $x_1 - x_2$ to any desired extent by increasing b.

6. *Convenient size of base.*—A few figures may be given at once to show the kind of base that will give good results. Suppose f (the focal length of the camera) to be 1 foot, and let b be 100 feet. This is a comparatively modest base, which would generally be available by selectiug positions with care. Then if $x_1 - x_2$ be a quarter of an inch, or 0·021 feet,

$$F = 100/0{\cdot}021 = 4{,}800 \text{ feet, or nearly 1 mile.}$$

Now, how accurately can we measure the difference $x_1 - x_2$ and thus determine the distance of objects a mile away? Experience has shown that it is easy to measure a photograph within, say, a thousandth of an inch—no one will think this too severe a limit. It corresponds to 1″·5 on the astrographic plates, and most observers would concede a division by at least 10. But we must remember that terrestrial objects may not be as well defined as stars, and so we will take an outside limit, say 0·001 inch. This

would correspond to an error of 1/250 of the distance at a mile away, say 20 feet; and this is considerable accuracy. For other distances the error is as the square of the distance, *e.g.* at 5 miles it would be 500 feet.

7. *Second method. Advance in direction of view.*—The formulæ, when we keep X the same, are equally simple. We have

$$\left.\begin{aligned} f/x_1 &= F_1/X \\ f/x_2 &= F_2/X \\ F_1 - F_2 &= b, \text{ say} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Thus $$f\left(\frac{1}{x_1}-\frac{1}{x_2}\right)=b/X$$

or $$\left.\begin{aligned} X &= \frac{b\,x_1x_2}{f(x_2-x_1)} \\ F_1 &= \frac{bx_2}{x_2-x_1} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

and obviously $$Y_1=\frac{F_1}{f}y_1$$

The weak point in this case is that when $x_1=0$ we have $x_2-x_1=0$: that is, the method fails to give results for objects near the middle of the picture. There is, however, a corresponding advantage in the adjustments of the instrument, as will presently appear.

8. *Necessary conditions.*—It remains to consider how to secure the necessary conditions, which are:

(1) To measure a base of a given length in a given direction. The practical difficulties here are such as need not concern us.

(2) To keep the camera parallel to itself. For this the camera should first be fitted with at least two cross levels. No reversal of the levels is necessary, as it is only necessary that the camera should be parallel to itself; but if the levels have serious errors, the survey will not be referred to a true horizontal plane. The levels will check the parallelism so far as rotations about horizontal axes are concerned. As regards that about a vertical axis,

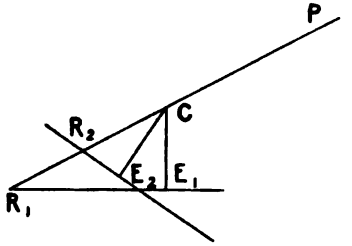


FIG. 2.

remark that in the second method this adjustment is checked by the pictures themselves, for objects at the middle of the picture

should not be displaced at all; and any displacement at once shows lack of parallelism. There is no difficulty in applying the correction for lack of parallelism, which takes a form already familiar in astronomical work. Let C be the centre of the lens, E_1R_1, E_2R_2, the correct and displaced positions of the plate; P an object which forms images at R_1, R_2.

Then
$$\left.\begin{aligned} E_1R_1 &= f\tan\theta \\ E_2R_2 &= f\tan(\theta-a) \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where a is the angle of displacement and may be supposed small.

Hence
$$E_2R_2 = f\tan\theta - fa\sec^2\theta$$

or
$$E_2R_2 - E_1R_1 = -fa\left[1+\left(\frac{E_1R_1}{f}\right)^2\right] \quad . \quad . \quad . \quad (10)$$

Thus the displacement of an object near the middle of the plate is nearly constant and measures the constant fa with accuracy. And for other objects we multiply this correction by a simple factor.

9. For the first or stereoscopic method the determination of this fundamental adjustment is not quite so simple, as all the objects in the picture are shifted. A compass-needle on the camera would not give the parallelism with sufficient accuracy when the base is small. If there is one object in the picture whose distance is accurately known, the error of parallelism could be found; but if the object is near, a considerable accuracy in its distance is necessary. The best general methods of securing this parallelism would probably be found only by experience; but that there is no essential difficulty may be seen from the following suggestions.

(*a*) If a cross telescope were attached to the camera it could be pointed on a distant object, the same in each position; or,

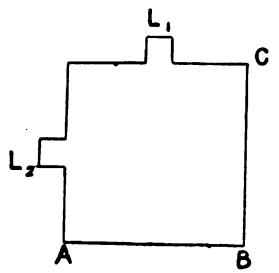


FIG. 3.

better still, two objects in line, such as two staffs set up for the purpose.

(*b*) Suppose a camera fitted with two lenses in two adjacent

faces ; L_1 giving a picture on a plate AB, and L_2 on a plate BC. Let both pictures be taken without moving the camera. Then advance 100 feet, either in the direction BC or BA, and take another pair of pictures. If in the direction BC, then the pair with lens L_1 will give an accurate measure of the error of parallelism, which can be used to reduce the pair of stereoscopic pictures taken with L_2. It should be remarked that fig. 3 is only the ground plan of the cameras, which can be separate instruments firmly attached together with lenses at right angles. The image formed by one lens could be reflected by a diagonal reflector on to the same plate as that formed by the other.

(*c*) If only one camera is available it can be made to serve as a pair at right angles, even without any accurate instrument for measuring angles. Nail two laths with straight edges at right angles to one another on a board, and place some fiducial edge of the camera against each in turn, taking care not to move the board between the exposures. There should be no real difficulty in securing this adjustment even in field work.

10. *Form of camera.*—It will be seen that no special form of camera is necessary, and probably the most convenient will be the simplest : a rectangular box with no focal adjustment, or better, two such firmly attached at right angles, would give good results. Either films or plates might be used, but if films, then a plate of réseau lines should be fixed immediately in front of the film. In any case there should be at least one set of cross-wires to identify the origin for measures on the two plates.

11. *Optical distortion* need not be a trouble even though it be large, as may happen with a wide-angle camera. It should be *determined* thus : expose the camera to any view first with the aperture which is to be used in practice ; secondly with a pinhole stop : measures of the two pictures will at once give the correction for distortion at different distances from the optical centre.

12. *The measures* should be made by the method of rectangular coordinates, in any of the ways found convenient for star measures. A series of réseau lines impressed on the plate is almost a practical necessity, but there is no need to dwell on points of this kind which have already been worked out in the case of star-measures. It may be remarked incidentally that a good deal of useful work might be done without taking photographs at all, by measuring the positions of images on the ground glass of the camera, or a substitute. If the substitute be a photograph of réseau lines, and an eyepiece with a cross-scale attached to it be placed carefully in contact with this photograph, so as to focus objects in the field of view, the réseau lines, and the cross-scale altogether, measures of position could be made at once, and a few such would doubtless be a valuable check on the photographic measures.

13. *General plan of survey.*—The following general plan of operations may thus be suggested. On any route, however

irregular, there will be opportunities for selecting pairs of stations accurately in the line of march, and 100 feet apart (or some other convenient distance). By pairs of photographs taken as above the positions of near objects can be determined well, and those of distant objects not so well. But these latter will appear on many photographs, and we thus get longer bases from which to determine them more accurately. A compass needle attached to the camera, though useless for avoiding minute differences of orientation, would be very useful in comparing results at distant stations.

On the Accuracy of Measures on Photographs: Remarks on recent Papers by M. Loewy and Mr. H. C. Plummer. By Arthur R. Hinks, M.A.

In the supplementary number of the *Monthly Notices*, 1901 (vol. lxi., p. 618), Mr. H. C. Plummer has recently discussed the very elaborate memoir by M. Loewy, "Sur la précision des mesures des coordonnées rectilignes des images stellaires," in the eighth circular of the *Conférence astrophotographique internationale de Juillet* 1900. M. Loewy has sought to find a general formula which shall give the probable error of the mean of a number of settings upon a star image, in a number of different orientations of the plate; and concludes that to avoid systematic error it is necessary to measure the plate in four orientations. Mr. Plummer has rediscussed the figures which M. Loewy gives, and comes to a number of conclusions, of which the most important are:

"(4) By combining measures made in the direct and reversed positions of the plate a much better result is obtained, to which M. Loewy's formula does *not* apply.

"(6) The error eliminated by reversing the plate is definite for each image, but may vary both in magnitude and in sign from one star to another."

Briefly, the principal point in dispute is, Can a sensible compensation of the systematic errors of measurement be obtained by measuring the plate in two positions whose orientations differ by 180°?

My excuse for intruding into the discussion between M. Loewy and Mr. Plummer at this point is as follows: For some months I have had the pleasure of being in correspondence with M. Loewy in reference to certain aspects of the question; he has been so kind as to give me very full and interesting explanations of his views; and I have his permission to give some passages from his letters in the present note.

At the beginning of his memoir (*loc. cit.*) M. Loewy says:

"Il y a donc à distinguer, lorsqu'on détermine une co-

ordonnée rectiligne, deux catégories d'erreurs : l'une, l'erreur accidentelle E_a, et l'autre, E_s, l'erreur systématique. . . . L'erreur totale E_t se trouve donc exprimée par la formule

$$E_t = \sqrt{E_a^2 + E_s^2}. \text{ "}$$

Now it is evident at once, as Mr. Plummer has pointed out, that the expression "systematic" error is not used here in its ordinary sense ; truly systematic errors of course do not follow the law of distribution which is the basis of the method of least squares. And to destroy the validity of the above equation it would be necessary to show only that the distribution of error in photographic measures is not entirely accidental ; that it tends to be of opposite sign in opposite orientations of the plate for example.

On this point M. Loewy writes (1901 October 16) :

"Je saisis cette occasion de préciser d'avantage la principe qui m'a guidé dans l'établissement des formules.

"Une fois la moyenne d'une série de pointés formée, ce résultat est affecté de deux catégories d'incertitudes, l'une a pour expression E_a/n" [apparently a slip for $E_a/\sqrt{n}$] "et l'autre est représentée par E_s.

"E_s est une erreur accidentelle d'une autre espèce affectant la moyenne. . . .

"Or, les expériences ont montré que, lorsqu'on répète les mesures dans une même orientation, avec un même observateur, après plusieurs mois d'intervalle, E_s varie notablement. Pour ce motif, on préfère ne répéter une seconde fois la détermination des coordonnées rectilignes que plusieurs mois après l'exécution de la première série de mesures. . . . Il n'est permis ici de faire aucune supposition sur une loi quelconque qui relie entre elles les différents valeurs de E_s, soit en signe, soit en grandeur. E_s est évidemment à considérer comme une erreur accidentelle d'un autre genre.

"Comme il convient, d'un côté, d'attribuer le maximum d'effet aux sources d'erreurs, et qu'il fallait d'un autre côté embrasser la généralité des cas, j'ai dû admettre qu'il n'existe aucun lien entre les E_s relatives, aussi bien à différents observateurs qu'à diverses orientations, même si celles-ci diffèrent de 180°—ayant fait d'ailleurs, comme je l'ai dit dans ma dernière lettre, des expériences qui confirment cette dernière hypothèse."

These experiments are thus described in a former letter (1901 September 12) :

"On a généralement admis, ainsi qu'à Paris, que cette petite anomalie constante dans une orientation donnée, s'élimine dans la moyenne de deux séries de mesures faites dans des orientations différant de 180°. Comme cela a été expressément répété dans plusieurs endroits de ma note, on ne peut admettre *a priori* aucune hypothèse, quelque soit son degré de probabilité, lorsqu'il s'agit d'atteindre le dernier degré de précision.

"Nous avons fait sur cette question de nombreuses expériences, avec divers appareils, et dans des conditions variées, et j'ai reconnu que dans le plus grand nombre des cas cette supposition est absolument inadmissible. On arrive *à peine* à une compensation partielle d'erreurs que dans des cas exceptionnels. . . .

"Dans le cliché que nous avons examiné, grace à ces qualités, il s'est produit dans les nombres relatifs aux positions différant de 180° quelques compensations ; mais elles sont de peu d'importance, en regard de la somme totale des résidus. En effet en formant d'abord deux à deux la moyenne des résidus entre les positions différant de 180°, et calculant après l'erreur probable, on trouve une valeur à peine différente d'un centième de seconde d'arc de celle figurant dans ma note."

To sum up briefly M. Loewy's view, it is necessary to consider "l'erreur systématique" as an accidental error of another kind, that is to say, differing from the accidental error deduced from the divergence of successive pointings in a single orientation, because, in the first place, experiments have shown that the systematic error is certainly not really systematic, but varies from time to time, and secondly because a rediscussion of the observations on the supposition that there may be some compensation when the plate is reversed leads to the original result. Now this is in absolute contradiction to the result which Mr. Plummer deduced from the same figures. And the discrepancy is of the highest importance because the validity of M. Loewy's fundamental equation turns upon it. If the "accidental error of another kind" can be shown to be not really accidental, if the errors in the measures of a given image in a given orientation of the plate are not equally likely to be positive or negative, then E_s is not an error which comes within the operation of the ordinary theory of errors, and the whole of M. Loewy's theory which follows on his fundamental assumption breaks down.

In a case such as this, where the validity of the application of the method of least squares is in dispute, there is at any rate a formal advantage in examining it from a point of view which does not involve the deduction for after-comparison of probable errors by the usual laws. I have therefore examined a part of M. Loewy's figures as follows.

His plate has a triple exposure, and 82 triple images were measured by two observers, A and B, in four orientations. Both M. Loewy and Mr. Plummer have treated the means for the three exposures as one complete measure. There is, however, a certain advantage in considering the exposures separately. Again, both have discussed the residuals of each setting from the mean of all for the two observers. Apart from the question which Mr. Plummer raises whether the two observers are equally skilled, there is a curious discontinuity in the results for B that leads to the suspicion that parts of certain columns of his figures have been interchanged. I fully agree with Mr. Plummer that this discontinuity is manifest—it appears in the measures for the

separate exposures, as well as in the mean for the three; and I propose therefore to discuss only the measures of observer A.

In Tables VI. 1 and VI. 2 of M. Loewy's paper we find the individual measures made upon the first and second images of each of the 82 stars, in four orientations, 0°, 90°, 180°, and 270°. Forming afresh the means for observer A only, we obtain from his measures 656 residuals. The point to be determined is whether these tend to be of opposite signs in opposite orientations. We will consider separately the pairs of opposite orientations 0° and 180°, 90° and 270°, and divide each series into two classes—I., in which the residuals in opposite orientations are of the same sign; II., in which they are of different signs. If the residuals are distributed impartially, both as to sign and magnitude, these two classes will be equal. We will further subdivide each class according to the magnitude of the sums of the pairs of residuals, without regard to sign. Again, if the residuals are distributed impartially, large numerical sums will occur with equal frequency in each group.

The results of this analysis are as follows:

Classification of Numerical Sums of Residuals in Opposite Orientations.

	0° and 180°.		90° and 270°.	
Exposure 1.	I. Same Signs.	II. Opposite Signs.	I. Same Signs.	II. Opposite Signs.
Sums between 0 and 19	13	7	7	9
20 „ 39	7	16	8	24
40 „ 59	8	12	9	13
60 „ 79	2	7	2	5
80 „ 99	1	3	1	2
100 and over	0	6	0	2
	31	51	27	55
Exposure 2.				
Sums between 0 and 19	13½	9½	14½	9½
20 „ 39	13½	18½	15	13
40 „ 59	3	6	3	14
60 „ 79	0	7	0	9
80 „ 99	0	4	0	2
100 and over	1	6	1	1
	31	51	33½	48½

The halves appear because in some cases one residual is zero, and the pair has to be divided between groups I. and II.

These numbers give abundant support to two conclusions:

(1) That in pairs of opposite orientations the residuals are more frequently of opposite sign than of the same sign.

(2) That when the residuals are large, and their numerical sum correspondingly large, they are almost always of opposite sign.

It seems to me, then, that these residuals cannot be treated as accidental in any sense whatever; that they do not come under the operation of the ordinary law of accidental errors at all; and that consequently M. Loewy's fundamental equation is not valid. I do not therefore find myself in agreement with Mr. Plummer when he says: "We may follow M. Loewy in denoting the accidental and systematic errors by E_a and E_s respectively, and the total probable error by E_t and admit that $E_t^2 = E_a^2 + E_s^2$." This is indeed in obvious contradiction to his conclusion that there is a striking compensation of errors when the plate is measured in reversed positions—a conclusion which is entirely supported by the figures given above.

One can scarcely avoid coming to the conclusion that it will be wise to hesitate before committing oneself to the arduous programme which M. Loewy recommends; and this view is supported by the circumstance that there is another category of error, of which he has not up to the present time taken any account, the real error of position of the star image on the plate, due to such causes as irregularity in the size or distribution of the particles of silver in the image, or local shrinkage of the gelatine film which is not eliminated by the use of the réseau. It is not possible to discuss the magnitude of this source of error on M. Loewy's plates, because he has given the measures of one coordinate only, and one cannot discover whether there has perhaps been a slight change of orientation, &c., in the interval between the exposures which would affect the differences between the coordinates with an error which is a linear function of those coordinates. It has, however, been abundantly proved that this third category of error may exist; it is not possible to deduce an estimate of the real accuracy of the resulting positions of the star from an examination of the discrepancies between the measures on a single exposure, or set of exposures treated as one, however carefully the conditions of measurement may be varied. The ultimate test is the agreement between the results of two separate exposures when one is rigidly reduced to be comparable with the other, if necessary. And it should be noted that a really systematic error in measurement, if such exists, unchanged from star to star, is of no moment, because it is eliminated by the process of finding from known stars the correction to the plate centering.

It seems to me, then, that the following process gives an estimate of the probable error of a complete measure which is a trustworthy guide to the real accuracy with which relative star places can be obtained from a photograph. Take two exposures immediately following one another: measure them, and examine (1) whether the differences between the measured coordinates of the two exposures depend upon the position of the star upon the plate; (2) whether they vary with the magnitude of the star, as they may possibly do if the guiding is not perfect. If they pass this examination, the divergences of the differences from the

mean will be a criterion of the inaccuracy which arises from all those categories of error, accidental error of setting, systematic error of measurement due to personality or otherwise, and systematic error of position of image due to irregularity or local defects. It is, then, of no consequence to examine elaborately the divergences from the mean of settings on a single exposure.

Cambridge Observatory:
1901 *December* 12.

The Spectrum of Nova Persei from 1901 *February* 28 *to April* 26. *With Appendix on the Spectrum in September.*
Rev. W. Sidgreaves, S.J., Stonyhurst College Observatory.

Introduction.

In "Notes on the Spectrum of *Nova Persei*," presented at the March meeting of the Society, it was briefly stated that the notes referred chiefly to photographs obtained with an objective prism of 4 inches aperture mounted on the finder of the large equatorial. It is necessary to preface the present paper by a more detailed description of this prismatic camera, on account of the difficulties which had to be overcome in order to secure accurate settings of the spectrum on the photographic plate. The importance of this adjustment is many times greater when the object-glass is corrected only for the visual rays than when a correcting lens for the photographic rays is employed, on account of the steep inclination of the plate to the optic axis of the lens, required for the simultaneous focus of the several photographic rays.

The camera is provided with a rotating frame for carrying the dark slide, and a graduated circle for setting the angle of inclination required. Another slide of the same dimensions as the dark slide carries three platinoid wires drawn taut over screw-heads—a pair of parallel wires, and one at right angles to the pair. When this slide is in the camera the wires lie in the plane to be occupied by the photographic plate. Its structure is simple, consisting of a plate of hard wood, with a central hole over which the wires are drawn, and side rails bringing up the sliding thickness to that of the dark slide. The space between the rails is left open at the ends to admit the light of a taper to illuminate the wires.

When the star is in the field its spectrum is seen with an eyepiece at the back of the camera as a sharp colour line, red at one end and blue at the other, together with the wires. The camera is set in position with reference to the prism by turning it in its adapter to bring the pair of lines parallel to the colour line image of the star; and the spectrum is brought into position on the

plate by setting it between the parallel wires, with the cross wire cutting out the yellow part of the spectrum. In this operation the eye has to be satisfied that there is no bluish-green on the red side, and no orange-yellow on the violet side of the cross line. This cross wire or bar is fixed not centrally in the field, but considerably to the side of the less refraction of the prism, in order to keep the photographic spectrum nearer the centre of the plate.

The length of the spectrum is 21 mm. from Hβ to Hν. About one-fifth of this is by the secondary spectrum of the object-glass, brought into service by the inclination of the plate.

With this inclination at 36°·5, Hβ and the region at and beyond Hι can be brought into simultaneous focus, and a shorter focus of about a millimetre brings the intervening region to the best definition. The latter adjustment has been employed on every date except February 28, when an error was made with the focus rack. The former was employed only on March 3, 12, and 16. The difference between the two focal lengths is not too great to hinder a compromise between them; and this has resulted occasionally from imperfect settings when the light of the star was too weak, or that of the sky too strong for seeing easily the yellow part of the spectrum.

The tube of the telescope is mounted so as to turn easily on its axis. This is a convenience for an adjustment to compensate for changing refraction, when the star is low and away from the meridian; and by it the slant of the spectral lines of the *Nova* has been greatly diminished, but only fully corrected on the later exposures.

The succession of fine nights in the earlier part of February came to an end on the 20th, just before the new star made its appearance. It was followed by a week of unbroken cloud until 10.30 P.M. of the 28th; and since then no opportunity has been lost of observing the spectrum of the star, in order to collect all information possible about the subsequent changes in its structure, which had been very great and very rapid in the early days of its life.

It was during the preceding fine week that the experimental work for selecting the angle of inclination of the plate and finding the focal adjustments had been completed for the ordinary photographic rays; but nothing had been done for an orthochromatic plate. And since the inclination of the plate for the green and yellow rays would have to be practically nothing, it was decided to make no attempt on these with the prismatic camera, but to leave them to the direct compound prism attached to the greater telescope; and thus the angle of inclination, on which all measurements in the spectra so much depend, has not been altered since its final selection. But only one isochromatic plate (Edwards) has been employed on the *Nova*, viz. on February 28, while the star was bright enough to give its green spectrum, to which the plate is only feebly sensitive.

Discussion of the Spectrographs.

1. *The continuous spectrum* of the star is remarkable for its great relative strength in the ultra-violet region. Compared with other stars, whether of the white or yellow type, the density of the silver deposit in the region near and beyond the head of the hydrogen series should be accompanied by a density in the blue region, at least equal to the darkest parts of the negative between Hβ and Hγ. It was, therefore, at the beginning, a question between two opposing interpretations of the spectrum : Whether it was to be called a strong, continuous spectrum crossed by broad absorption bands and the bright hydrogen series, or a weak continuous spectrum with bright bands. The former interpretation seemed to be more in keeping with the earliest observations at Edinburgh and Harvard College. But there are two regions on the plates, which cannot be accounted for on the supposition of a strong continuous spectrum. These are the region near Hβ on the violet side, and the region between Hδ and Hϵ : these are much too weak, when compared with the strongest parts between Hβ and Hγ, to be considered continuations of the same spectrum. The later photographs of March 22, 25, and 28 seemed to decide the question in favour of the bright blue bands by their greater prominence on a weaker continuous spectrum.

2. *The bright hydrogen lines* are probably the broadest radiation lines yet observed in stellar spectroscopy. In the following table their widths on the negatives are given in millimetres, with a column of means reduced to spectral widths in wave-length micromillimetres :—

TABLE I.

Widths of Hydrogen Bright Lines.

	On March 3 mm.	16 mm.	27 mm.	April 4 mm.	16 mm.	Mean mm.	Mean $\mu\mu$
Hβ	0·44	0·34	0·35	0·33	0·29	0·35	3·5
Hγ	·68	·63	·56	·48	·53	·58	3·5
Hδ	·78	·79	·59	·64	·53	·67	3·4
Hϵ	·83	·81	·72	·59	·68	·73	3·2
Hζ	·96	·89	·72	·72		·82	3·3
Hη	·78	·77	·60			·72	2·7

These figures show an apparent gradual shrinkage of the lines. But it may be doubted whether this is a real contraction or only the result of decreasing intensity. The widths on March 3 and 16 are exaggerated by over-exposure of the hydrogen spectrum ; and those of March 27 and April 4 may be broadened in the same way by a rate of trail slower than was intended for the diminished magnitude of the star. On the other hand, the trail was too quick on April 16, through an accidental omission to adjust the clock rate ; but the definition

3. *The calcium line* K was bright and broad like the hydrogen bright lines on February 28 and March 3, and since then it has slowly faded away. It was marked with a central reversal, and the more refracted half was much the weaker. This was the first to disappear; it was weaker on March 7 and 8; and on March 12 it was extinct; but the reversal remained as a companion to the stronger component. On this date the reversal was a strong, sharp, and thin line on the more refracted side of its bright companion, resembling the dark companions of the hydrogen bright lines, but retaining its position of the K wave-length relatively to the bright hydrogen series. It is again apparently marked on the plate of March 16, but only about half across the plate, viz. during the first part of the trail; and so, if real, it was extinct at 8.30 P.M., the trail having started at 8^h and ended at 9.15. Its position is exact; and it is very nearly, if not perfectly, parallel to Hϵ. It divides nearly centrally a feebly bright space, which may be calcium radiation nearly extinct; and this trace of calcium light is seen again, and for the last time, on a plate of the 21st without the reversal.

4. *The dark hydrogen lines* do not appear to have been, at any time, very broad; not much broader than those of α *Geminorum*.

In the first photographs of February 28 and March 3 there is nothing against the possibility of a much greater width masked by the overlapping broad bright lines. But on the later photographs they stand apart from the bright lines, with perfectly sharp edges, and the broad bright lines fade away towards them in the same manner as they fall off on the red sides. This is very clearly seen in Hδ, Hϵ, and Hζ in the enlarged spectrographs of March 12, 16, and 21.

At the beginning these dark lines appeared to grow in strength, between February 28 and March 8; but the evidence for this is not conclusive: the apparent increase of intensity may be a photographic effect due to difference of exposure. But after March 8 their decline was regular and uninterrupted; they slowly disappeared, together with the bright calcium line K. On March 12 they had lost their centres, and appeared as well-defined double lines separated by a thin clear reversal. The more refracted components were much the weaker and were the first to disappear. They had lost much on the 16th and were quite extinct on the 20th, when the red side components formed the series of sharp thin lines, which were seen for the last time on the 21st.

5. *The separation of the bright and dark hydrogen lines* is still the most important feature of a *Nova's* spectrum. The separation in this spectrum is so great that it is not necessary to wait for direct determinations of displacement with reference to terrestrial hydrogen light in order to arrive at sufficiently approximate conclusions, on Doppler's principle, regarding the line of sight velocities. The measured length of the hydrogen

spectrum compared with that of a reference star, on the method described by Orbinsky,* may be considered enough for the investigation of velocity by small dispersion, when an error of 50 miles is of no great consequence.

For this investigation the reference star selected was *a Cygni*, on account of its sharply defined hydrogen lines. Four exposures have been made with the correct *setting*, described in the introduction, and three with a faulty setting, more at fault than could occur accidentally. All these have been carefully tested on the micrometer stage; and the agreement of the measured lengths from Hβ to the several hydrogen lines up to Hμ is expressed by the greatest difference between the same measures on any two of the plates being ·02 mm. Repeated measures of the same intervals on the photographic plates of the *Nova* have been made, and the results are summarised in the following table; in which the figures of column j are the measured lengths from Hβ to the successive hydrogen lines in the spectrum of *a Cygni*, and those of column ij are the corresponding lengths in the dark-line series of *Nova Persei*. In column iij the differences are entered, and in column iv the deduced velocity. In columns v, vj, vij, viij the bright lines are treated in the same way as the dark lines in j, ij, iij, and iv :—

TABLE II.

Radial Velocity.

Hydrogen.	Dark line spectrum.				Bright line spectrum.			
from Hβ. to	Length a Cygni. j. mm.	Length Nova. ij. mm.	Diff. iij. mm.	Deduced velocity miles per sec. iv. −	Length a Cygni. v. mm.	Length Nova. vj. mm.	Diff. vij. mm.	Velocity Miles viij. +
Hγ	6·990	7·081	·091	720	6·99	6·95	·04	320
Hδ	11·376	11·509	·133	740	11·38	11·33	·05	280
Hε	14·268	14·426	·158	700	14·27	14·23	·04	†180
Hζ	16·226	16·428	·202	770	16·23	16·15	·08	300
Hη	17·625	17·835	·210	710	17·62	17·54	·08	270
Hθ	18·654	18·878	·224	720				
Hι	19·433	19·660	·227	690				
Hκ	20·032	20·263	·231	700				
Hλ	20·505	20·745	·240	710				
Hμ	20·882	21·120	·238	680				
	Mean			− 714.		Mean		+270.

No great accuracy is to be expected in the resulting velocities. But the figures afford an independent demonstration of

* Observatory, 1895, 303.

† There is some reason for mistrusting the apparent centre of this line on account of the presence of other lines, as may be gathered from the remarks upon the line 396·9 in the Appendix.

high velocities in opposite directions, together with an approximate measure of their magnitudes. Those from the dark-line spectrum rest on the measures of a single plate for the greater intervals at $H\iota$, $H\kappa$, $H\lambda$, $H\mu$, and on three plates for the shorter lengths.

There was little difficulty in setting the micrometer wire on the absorption lines, which are sharp and well defined. It was different with the broad bright lines, but for these many plates were available; and the mean intervals obtained from them should give a fairly reliable resulting velocity, seeing that the individual measures are not very erratic. The following table contains an abridged analysis of these measurements, designed to show the relation between the *means* and the separate measurements :—

TABLE III.

Analysis of the Measurements for the Bright-line Velocity.

Relation between the *means* and *separate measures.*

From Hβ to		Hγ	Hδ	Hε	Hζ	Hη
Mean length	mm.	6·95	11·33	14·23	16·15	17·54
Number of plates affording a measure		26	22	23	14	12
Range, or difference between extreme measures	mm.	·07	·09	·13	·21	·33
Number of measures giving the opposite sign		1	1	3	0	1

The resulting velocities were in both cases unexpected, as may be seen by a reference to the writer's earlier notes on the spectrum of *Nova Persei* in the *Monthly Notices*,* in which it was stated that the whole of the relative velocity would probably have to be attributed to the dark-line source; the measured lengths from Hβ to the successive bright lines being the *same* in the spectrographs of the *Nova* and of the comparison stars. The *differences* have been found by comparisons with the thinner and more sharply defined hydrogen lines in the spectrographs of *α Cygni*, obtained at the end of May and beginning of June.

There is no evidence from this investigation of any change of the velocity of the bright-line source between March 3 and April 26; but, so far as the measures can be trusted, the evidence is for a constant velocity. Of the total number of plates measured, eighteen belong to March and eight to April; and the mean lengths are compared in the following table :—

TABLE IV.

From Hβ to	Hγ	Hδ	Hε	Hζ.
Number of plates in March ...	18	17	17	12
„ „ April ...	8	5	6	2
Mean length in March ...	6·95	11·33	14·23	16·15
„ „ April ...	6·95	11·33	14·22	16·17

* April 1901, Note 2.

6. *The general spectrum of the star* is treated as two distinct spectra, called for convenience the *approaching* spectrum and the *receding* spectrum. The receding spectrum is taken to consist exclusively of bright lines. These are, with few exceptions, like the hydrogen lines, broad and somewhat diffuse; and they are supposed to be under the same physical conditions which affect the position and breadth of the hydrogen lines.

The wave-lengths are quoted for the centres of the broad lines; the centre of bright Hβ has been employed for the fiducial point in the receding spectrum, and the wave-lengths have been corrected for velocity-displacement.

Similarly, in the approaching spectrum the centre of dark Hβ, or of dark Hγ, according to the circumstances of the plate, has been used for the fiducial point, and the displacement correction applied accordingly.

In both spectra, therefore, the tabulated wave-lengths are, as nearly as can be obtained from the spectrograms, the undisturbed wave-lengths of the origins, or as they would be found from a stationary source. A test line for the corrections of the receding spectrum is the reversed K, which is a thin sharp line on the plates of March 3, 12, and 16, and owing to the applied correction appears in the table with its undisturbed wave-length.

The tables are to be found at the end of the paper; and the lettering of the columns and explanations are given in the notes at the end of the tables.* In the first column of the bright-line table some possible origins are noted, which are collected together in the following list. The wave-lengths are taken from Watts' Index, excepting those of helium, which are the strongest lines in Runge and Paschen's list: †—

TABLE V.

Possible Origins of Bright Lines.

Nova. λ	Width. μμ	Helium. Max. I.	10.	Oxygen. Max. I.	10.	Magnesium. Max. I.	10.	Vanadium. Max. I.	10.
403·3	1·7	402·6	5						
407·0	2·1			406·9	6				
				407·1	6				
				407·5	6				
								437·9	10
438·3	Thin	438·8	3					438·4	1
								439·5	6
447·1	Thin	447·2	6						

* It was originally intended to give the tabulations separately for the dates at the heads of the columns of spectrum I. and spectrum II., which are respectively the *old* and the *new* spectrum of the text. But when it was found that another new spectrum was presented in August, it was decided to put the three spectra together side by side, and to simplify the tabulations of all.

† *Harvard Coll. Ann.* xxiii. pt. i. p. 123.

Nova. λ	Width. μμ	Helium. Max. I. 10.	Oxygen. Max. I. 10.	Magnesium. Max. I. 10.	Vanadium. Max. I. 10.
447·9	0·7			448·1	
457·2	1·7			457·1 10	
458·6	Thin				458·5 6
464·0	3·0		463·7 6 464·1 7 464·8 9		
471·7	Thin	471·3 3			
491·9	3·4	492·2 4			
501·5	3·2	501·6 6			
				517·9 9	
516·7	3·9			518·3 10	

Also on March 28			
385·7	*Cyanogen*	385·7	7
386·1	,,	386·2	8
388·2	,,	388·3	10

An interesting result appears by collating the two tabulated spectra : viz. that the broad bright line near Hδ and the broad absorption on its more refractive side, which are well seen in the enlarged photograph of March 3, &c., are complements, having, practically, the same wave-length, 407·0 and 406·9, in their respective spectra. The line has a strong claim to represent the oxygen triplet, as noted in the table above ; and therefore oxygen appears to share the physical conditions of hydrogen in the *Nova*.

Other complementary lines, indicated in the same manner, are the fine lines

461·5	459·6	438·6 bright	on March 17.
461·4	459·3	438·5 dark	

7. *The alternating spectrum* of the *Nova* was first observed as such on March 28, when the photograph of the preceding day showed that the remarkable change seen in those of the 22nd and 25th was not a permanency. The changed spectrum is to be found on Plate 2 of enlarged photographs, on the dates March 25 and 28, which are in all details the same as the photograph of the 22nd. Its leading features are the broad blue lines or bands in conspicuous contrast on a much enfeebled continuous spectrum, and an apparent great extension of the bright hydrogen line Hζ. On the same plate is shown the return to the older spectrum on the 27th ; and the two similar spectra of the 21st and 27th show that the change from the old to the new spectrum on the 22nd and 28th was very rapid.

The three dates, March 22, 25, and 28, on which the new spectrum was first seen, corresponded closely with the observed

minima in the star's light curve; and the star was supposed to be a variable with a corresponding variable spectrum. But the three-day period failed at the end of the first week of April, the alternations of light intensity became irregular, and the spectrum followed the irregularities of the light. In the following table the dates of the two forms of the spectrum are given from March 21 to April 26; opposite each date the magnitude of the star is quoted from the measures made at the Radcliffe Observatory, Oxford,* and the items are written in the order of

TABLE VI.

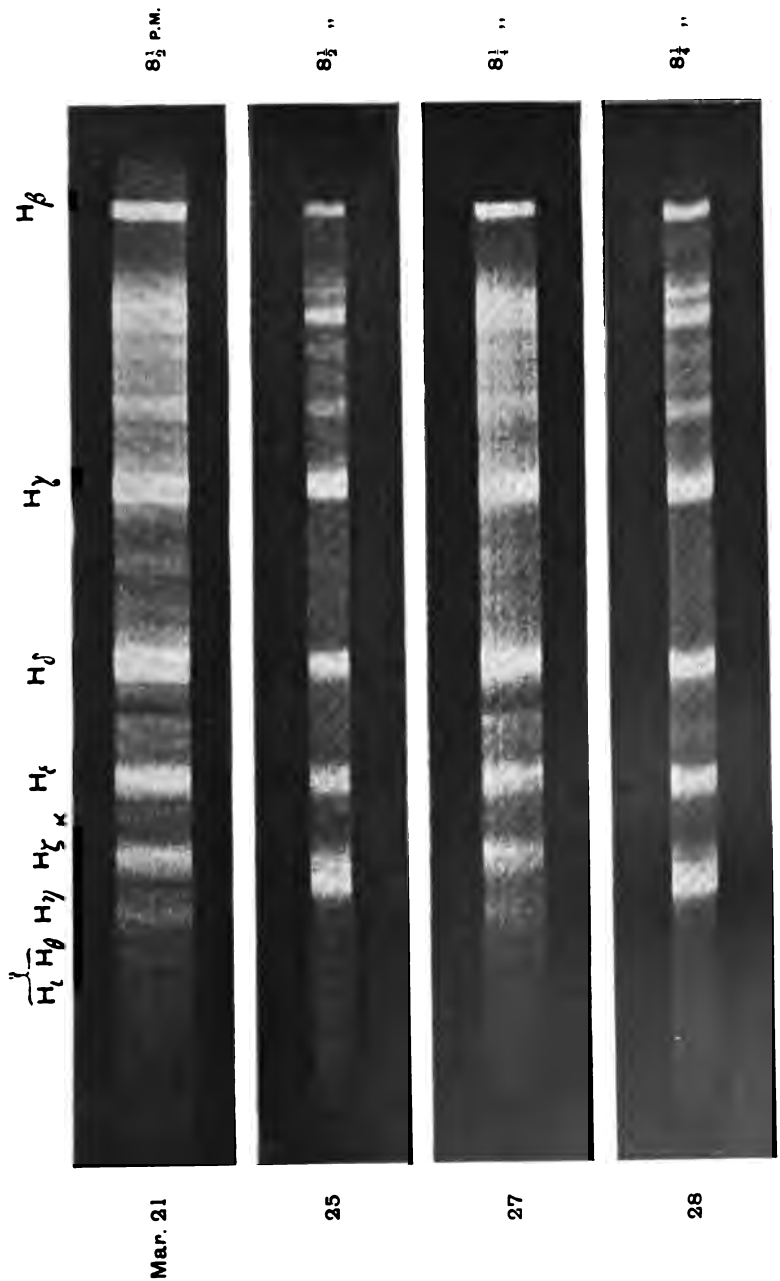
The Alternating Spectrum.

Star's Magnitude.	On Date	
3·91	March 21	
3·98	,, 27	
4·08	April 4	
4·19	,, 1	Old type.
4·28	,, 5	
4·36	,, 23	
4·49	,, 13	
4·57	,, 9	Both types partly.
4·61	March 28	
4·67	April 12	
5·15	March 25	
5·20	,, 22	
5·32	April 16	New type.
5·55	,, 26	
5·83	,, 20	
5·86	,, 25	
6·00	,, 21	

decreasing magnitudes. These figures show that the *new* spectrum is not connected with any phase of the light curve, but follows the absolute light intensity. All the *new* spectra have appeared when the star was less than 4·57 mag., and the *old* spectra only when the star was brighter; and this magnitude seems to indicate the temperature at which the change takes place: for the spectrum on this date, April 9, belongs partly to both types, the *old* and the *new*, as may be seen by a reference to the writer's note 4 in the May number of *Monthly Notices*, p. 463.

Of the blue bands in the new spectrum, the first (counting from Hβ) is a new radiation, λ 468·7 and the stronger one near it, λ 464·1, is also new if compared with the spectrum of

* *Monthly Notices*, 1901 April and May.



SPECTRUM OF NOVA PERSEI, 1901

Stonyhurst College Observatory

March 21; but it is within the very wide band at λ 465 $\mu\mu$ of March 3 and February 28. The fifth band (third in the order of brightness) is the helium line 4472, and is probably new; but it is broad enough to contain the magnesium line 448, which was the centre of the band on and before March 21. The less refrangible helium line at 471·8 is only just discernible in the negative of March 28, not seen so well as on March 16 and preceding dates.

The apparent extension of Hζ is also a new radiation, probably the cyanogen band between λ 388 $\mu\mu$ and 386. It is crossed by three distinct brighter lines, 388·3, 386·1, and 385·7, agreeing closely with the strong CN lines of intensities 10, 8, 7 in Watts' Index of spectra; but there is no trace of the line 387·1 of intensity 9. The band is brighter than Hϵ and nearly equal to Hδ in intensity.

Hϵ itself is too strong both with reference to Hδ and to the part of Hζ which is not overlapped by the CN band; and this disproportion in the gradations of intensity becomes a marked characteristic of the new spectrum on April 16, 20, 25, and 26, when Hϵ appears on the plates with double the strength of Hδ, although at the low altitude of the star on these dates the line should have been obliterated by atmospheric absorption. It is therefore probable that this is another new line.

Review.

At the end of a rather long study of the photographic plates of the *Nova's* spectrum, two questions appear to stand over, about which some expression of opinion may be expected. The first of these regards the high velocities: is Doppler's principle of motion in the line of sight to be accepted or rejected for the true cause of the great displacements of the hydrogen lines? And the second is about the new type spectrum first photographed on March 22: what is its teaching?

In an article "The New Star of the New Century" in the May number of *The Observatory*, the writer acknowledged his own dissatisfaction with the Doppler explanation of the velocities, mainly on account of the want of a general law, according to which the high velocity of the dark-line source in all new stars should be towards our Earth. This want was supplied by Lord Kelvin in a conversation at the Royal Society Soirée in May, and with his permission was explained verbally at the following meeting of the Royal Astronomical Society. The explanation subsequently appeared in the June number of *The Observatory*, and is reprinted here with the kind permission of the editors:—

"Granted a collision between two stars, the immediate result would be scattering of matter in all directions, with greatest velocities in directions nearly perpendicular to the line of relative motion of the two impinging bodies. These velocities of fragments may largely exceed that of the relative motion of the

two bodies before impact. The matter thus scattered would consist not only of the broken bits but also of their decomposed constituents. Ubiquitous hydrogen would be there to begin with, and much also would be liberated. A part of this gaseous mass would be raised to high temperature, with little associated kinetic energy; and a part would be urged outwards at high velocity, with little rise of temperature; and this, the cooler gas, would be the absorbing material. The absorber therefore would always be in motion towards us, and the radiant matter would remain at comparative rest. The application of Doppler's principle then becomes simple. The mass of hydrogen moving away from the white-hot centre would absorb shorter wave-lengths of the white radiation, and would *not* absorb the radiation of glowing hydrogen. The bright lines would therefore be little or nothing displaced on the continuous spectrum, and the dark lines would always be shifted to the side of greater refraction."

The explanation requires the actual collision of two solid stars to account for the enormous velocities needed for the Doppler explanation: no multitude of smaller masses in collision could produce the same effect; and no intrusion of a big solid mass into an ocean of nebulous matter would be more successful. In these hypotheses the fatal assumption has to be made of antecedent high velocity in a given direction. On the other hand, actual collision seems not only possible, but almost a certain occurrence from time to time in the vast and crowded region of the Milky Way; and no imagination can picture the results of the shock of two worlds meeting.

The second question regarding the alternating spectrum is more perplexing. The first change was great and sudden, resembling the quick transition from the white star spectrum to that of gaseous radiation in the earliest days of the star's appearance. But the change was not permanent; the old spectrum returned, and the two types of spectrum alternated quickly, at first periodically, and then at more or less irregular intervals. The quick transitions would be in keeping with some form of eclipsing revolution, but eclipses could not account for the development of entirely new radiations.

A suggestion was made by Sir William Huggins, as far back as 1866, in connection with the new star of that year in *Cygnus*, that the outburst of heat and light might be attributed to "a chemical action of some of the escaping highly heated gases from within, when cooled by the sudden expansion, which might give rise to an outburst of flame at once very brilliant and of short duration."* This hypothesis offers a much-wanted explanation of the oscillating spectrum of the *Nova* in the last days of March. The sudden expansion of a vast mass of mixed gases would naturally become oscillatory for a length of time, the temperature oscillating with it; and when the mean temperature of the oscilla-

* *Atlas of Representative Stellar Spectra*, p. 15.

tions was near the combining temperature of some of the mixed gases, the spectrum would also oscillate with the temperature.

This hypothesis has apparently been revived more recently * in a modified form, which does not appear to suit so well the requirements of oscillation. The difficulty comes in when, for the sudden expansion, radiation is substituted for the cooling agent. This is necessarily a slow process, and something is wanted to keep back the chemical action until the mass of elements ready for combination is great enough for the enormous evolution of heat required. Without this the result is only a retardation of the rate of cooling, as crystallisation arrests the fall of temperature of a cooling liquid. It is true that water may be cooled down several degrees below its freezing temperature, and when the ice forms the temperature rises; and we have, on a small scale, in the opposite process of heating water, an irregularly oscillating temperature about the boiling-point, when the generation of steam becomes rapid. The reach from these small operations to those that would be required for an oscillating stellar temperature is very great; but every supposition made implies some forbidding magnitude, and here the greatness is not greater than the step from the laboratory to the stellar experiment.

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Appendix.

On August 24 and 27, September 5 and 11, and October 4 and 6, good photographs of the *Nova's* spectrum were again obtained, and these show further changes which may be found to be connected with the fall of temperature during the interval.

The photograph on August 24 shows all the broad lines distinctly, but not the finer details: the rate of trail was too slow, and the stronger bands were over-exposed. The plate of September 11 shows, on the contrary, the details of the stronger bands distinctly, but the trail was too quick for the weaker bands.

The reproductions on Plate 3 are from the photographs of August 27 and September 5. The first of these is by the Hilger compound prism (marked H in the tabulations) on the large equatorial; and the second is by the Thorp 4-inch objective prism, T. The first shows the lines better in the blue and green, but loses the violet and ultra-violet by the great absorption of its dense flint glass. The second supplies the violet end of the spectrum. But all the bands can be seen in both.

Other photographs on September 14, 15, 21, and 24, in less favourable atmospheric conditions, serve to show that the spectrum has remained constant in September. It still retains

* Lohse, cited by Vogel, *A.N.*, 3701, and *Edinburgh Review*, 1901 July, p. 89.

its general character of broad bright lines on a distinct continuous spectrum, which perhaps cannot be called weak considering the small magnitude of the star. The principal changes are contained in the following notes :—

1. The hydrogen lines are no longer the prominent features. They are weak uniform bands, and are apparently dying out without losing anything of their width.

2. The two significant lines 500·7 and 495·8 have come into prominence, in place of the two helium lines 501·7 and 491·9, which have disappeared.

3. The blue helium line 447·2 has died out, and another, a weaker line in the laboratory, 471·3, has grown from a feeble intensity to be one of the strong lines of the spectrum : it is the strongest on the isochromatic plate by the prism H.

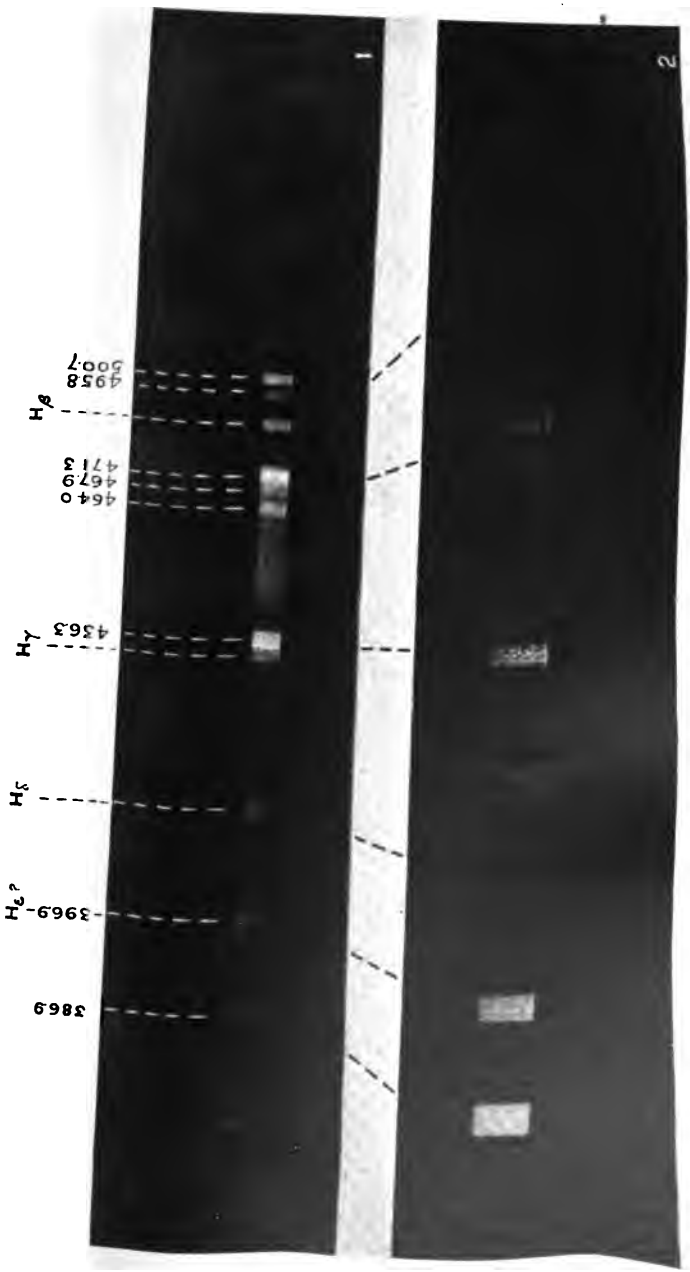
4. The strong broad blue band 468·7 of the new spectrum in March and April has contracted to a narrower and weaker band, at 467·9.

5. The hydrogen line Hγ and its companion band at λ 436·4 have exchanged conditions of relative intensity, the latter now being much the stronger. These two broad lines have been close companions from March 21. They overlap one another, and the overlapping edges can be seen in the photographs of March 21 and subsequent dates. They are very clear in the photographs of August, September, and October, and in these the overlapping strip is much stronger than the united intensities ; it has been interpreted as a bright line in the structure of the band 436·4, and is proved to be so by a photograph on September 15, in which it appears as a strong line on this band when Hγ and the other hydrogen lines have failed to mark the plate.

6. The three bands, 386·9, 396·9, and 436·4, are marked symmetrically, each with four brighter lines, and the brightest near the more refracted edge.

7. The strongest lines by prism T are 386·9, 396·9, 436·4, and 471·3, in order of decreasing intensities ; and of these the three first are apparently at the same intensities as in March and April. On March 25 the altitude of the star and the circumstances of the plate (exposure and development) were the same as on September 5, and the intensities of the bands are practically the same on both dates. But in March the bands had nebulous edges, and in September they are compact bands with well-defined edges, as on April 16.

8. The most energetic radiations of the star, allowing for appearances depending upon instrumental defects, are λ 386·9 and 500·7. It is not clear which of these is the stronger. The former is the strongest by prism T, and appears as a distinct though feeble band on the photograph by prism H, notwithstanding the prism's great absorption of this light ; while the latter is a strong line by prism H, although its position on the sensibility curve of the isochromatic plate is rather low down in the hollow between the blue and yellow maxima, and the line is



SPECTRUM OF NOVA PERSEI ON AUG. 27 AND SEPT. 5, 1901

1. BY COMPOUND PRISM ON LARGE EQUATORIAL
2. BY OBJECTIVE PRISM ON 4-INCH FINDER

Stonyhurst College Observatory

distinctly marked on an ordinary quick plate employed with the prismatic camera, although the sensibility of the plate to this radiation is very small. But this plate affords a direct comparison between the intensities of the *Nova* and the corresponding places in the continuous spectrum of *α Cygni*. The two spectra are not on the same plate, but both plates are Mawson's quickest, and the exposures and developments were practically the same, the exposure on *α Cygni* having been made with the object of bringing out every possible detail at the two extremities of the spectrum. In this comparison the line 386·9 of the *Nova* is decidedly stronger, and the line 500·7 a little stronger than the corresponding parts of the spectrum of *α Cygni*. The preference therefore is given to the ultra-violet line, and the probable order of real intensities in the *Nova*, beginning with the strongest, is 386·9, 500·7, 495·8, 472·0, and 436·4.

These and the weaker lines are entered in Table VII. under the name of spectrum III.; and the line-details of broad bands are given separately. These wave-lengths are not corrected for any velocity displacement, no indication of displacement having been found. On the photographs of August 27 and September 5, Hβ and Hδ appeared with well-defined edges admitting of accurate settings of the micrometer line, and no relative displacement was found.

We have, at Stonyhurst, no photographs of the spectrum between April 26 and August 24; and, unfortunately, no orthochromatic plate was employed in March or April: so that our series of photographs leaves it uncertain whether the new lines 495·8 and 500·7 on August 27 belong to the second spectrum, or to a further decrease of stellar temperature. The change at the position of Hε, where the band 396·9 is so much stronger than the other hydrogen lines, appears to be connected with the star's magnitude 5·32 on April 16, when Hε was stronger than Hδ; it was not so on a later date (April 23), when the star was much brighter, and it was not so on an earlier date (March 22), when the star was a little brighter—·12 mag.—and it was always so later, when the star was less bright than 5·32 mag. But the structure of this band, and the similar structure of the bands 386·9 and 436·4, belong probably to a later stage of the star's decline.

Of the changes, therefore, enumerated, perhaps only the following are to be associated with the lower temperature of the later spectrum: 1, the development of the band 472, which was weak and hazy in the second spectrum, into a strong band containing a stronger line at 471·3; 2, the shrinking of the strong band 468·7 of the second spectrum to a weaker and thinner band at λ 467·9; and 3, the quadruple structure of the three bands 386·9, 396·9, and 436·4.

The other changes may have taken place at higher temperatures. Thus the compact form of the bands is apparently a marked feature of the later spectrum—a change from diffusive

edges to sharp margins ; but from the photograph on April 16 this form appears to have been assumed at a higher temperature, when the star's magnitude was 5·32. Similarly, the predominating intensities of the lines 386·9 and 396·9 appear to indicate a comparatively permanent state of radiation, dating from the beginning of the second spectrum, and brought into relief by the failing of other lines, rather than by any growth of their own intensities.*

Conclusion.

It must be admitted that the latest spectrum of *Nova Persei* has not contributed to a better understanding of its earlier forms ; and has raised new questions, or possibly only emphasised old ones, which need solutions before we can read with certainty the messages from temporary stars. The great width of the lines was the leading difficulty at the beginning, but it was not insurmountable. Enormous velocity, or enormous pressure, could not be considered improbable physical facts, associated with the certainly enormous evolution of heat implied by the rapid rise of the star from nothing to the brightest in the sky. But the undiminished width of the lines during the last five months has strengthened the besetting difficulties : high velocity and great pressure present less difficulty when lasting for a short time ; but the hydrogen lines are as broad to-day as they were in the middle of April, and show no signs of losing width : they are apparently dying out uniformly, without thinning at the edges ; and the edges are now too firm and too sharp to give the impression of widening by velocity or by pressure.

The questions raised by the present form of the spectrum are not altogether new, but they are more pointed now that they are presented by a purely bright-line spectrum, without the crowded absorptions which might anywhere obliterate a bright line or reduce its intensity to an apparent abnormal relation to others of the same origin. The broad strong line 396·9 might belong to hydrogen, to helium, or to calcium ; but whichever be supposed, the question comes : Why are the usually stronger lines suppressed ? The calcium spectrum has been studied by Sir William and Lady Huggins, in relation to the density of the vapour giving the spectrum.† And they have found that in an extremely rarefied state of the luminous vapour there remain only the two strongest of its lines, known as H and K of the solar spectrum. But at every stage of the experiments the line K was the stronger, and both had become thin lines, losing their broad wings with diminishing density.

As a calcium line, therefore, in the *Nova*, it would be too strong and too broad, and without its inseparable stronger companion at K. As a hydrogen line it would be a case of the

* Cf. Notes, 7, p. 49.

† Huggins. *Atlas of Stellar Spectra*, p. 101.

weakest of four becoming stronger than the united intensities of the rest. And as a helium line, it would be a naturally weaker line in full strength while the strongest are wanting. But of these as possible origins helium, perhaps, is the more probable. Taken for the helium line 396·5, there would be, in all, three helium lines in the spectrum, 386·8, 396·5, and 471·3; all composite lines, but not all symmetrically marked, and not symmetrically widened, the centres of the three bands in the *Nova* being to the red sides of the helium lines at 0·1, 0·4, and 0·6 $\mu\mu$ respectively.

It may be in the future of spectroscopic work to discover the physical conditions of radiant matter when giving these anomalous spectra; but the simpler supposition of an unknown common origin of the three bands 386·9, 396·9, and 436·4, suggested by their perfect similarity in form and structure, may be true, and is perhaps more in keeping with our imperfect knowledge of the luminous spectrum.

But what is the origin? Should it be called Nebulum? Professor Pickering, writing at the end of June, points out the likeness, with some exceptions, between the spectrum of the *Nova* and that of the nebula N.G.C. 3918.* The likeness has improved since then in some respects, for the relative strength of the line 500·7 is better, and the line 436·4 is clearer: the former is now considerably stronger than Hβ, and the latter much stronger than Hγ. And there is no mention of the line 464·0, which was the strongest of the blue bands in the second spectrum, and is still equal to Hγ; while the other strong line 468·7 has either completely fallen out, or is masked by two side lines, a weaker one at λ 467·9, and the practically new line 472·0, which is now the strongest of the blue bands. But is not the likeness spoiled by the great width of the *Nova's* lines, and by the composite structure of four of the strongest bands?

TABLE VII.

Bright-line Spectrum of Nova Persei, 1901.

Spectrum	I.			II.			III.								
Prism	T.			T.			T.			H.		T. and H.			
Date	Feb. 28, Mar. 3, 12, 16, 21, 27.			Mar. 22, 25, 28.			Aug. 24, Sept. 5.			Aug. 27.		Oct. 4, 6.			
Nova Magnitude	Mag. >4·57.			Mag. <4·57.			6·21.		6·42.	6·48.		6·86.			
Possible Origins.	λ $\mu\mu$	W $\mu\mu$	i 10/1	λ	W	i	λ	W	i			λ	W	i	
	376·4	1·7	2												
Hθ	379 8	2·6	8												
Hη	383·5	2·9	5												
Hζ	388·9	3·3	6	386·9 388·9	6·0	8	387 0	2·9	10	387	2·3	386·8	T.	2·5	

* *A.N.*, 3735, p. 234.

Spectrum	I.			II.			III.					
Prism	T.			T.			T.			H.		T. and H.
Date	Feb. 28, Mar. 3, 12, 16, 21, 27.			Mar. 22, 25, 28.			Aug. 24, Sept. 5.			Aug. 27.		Oct. 4, 6.
Nova Magnitude	Mag. > 4·57.			Mag. < 4·57.			6·21.	6·42.		6·48.		6·86.
Possible Origins.	λ μμ	W μμ	i 10/I	λ	W	i	λ	W	i			λ W i
K	393·3	1·9	5									
He	397·0	3·2	7	397·1	3·4	8	396·8	3·2	8	396·8	2·5	396·8 T. 2 3
He 402·6	403·2	3·2	3	403·1	2·2							
O triplet	407·0	2·1	4	407·0	.							
Hδ	410·2	3·4	8	410·2	3·0	9	410·2	3·0	2	410·1	2·3	
	413·0	2·2	6	414	3	1						
	417·4	2·9	6	419	3	1						
	423·4	2·3	6	423·5	3	1						
	430·3	2·5	6	428	3	1						
Hγ	434·1	3·5	10	434·1	3·1	10	434·1	2·6	2	434·0	2·5	434·1 H. 2·3
O 436·4*				436·4	3·0	3	436·4	3·0	7	436·3	2 8	436·3 H. 3·0
	438·4	4·5	7	438·4	2·5	2						
He 447·2				447·1	3·2	4				447·1	2·7†	447·1 2·7†
Mg 448·1	447·9	0·7	7									
	452 0	1·5	7	452·3	3·3	1						
Mg 457·1	457·2	1·7	7	457·1	3·3	2						
O triplet				464·1	3·3	9	464·0	3·2	2	463·9	3·0	463·9 H. 2·5
	465·0	6·3	7									
							467·9	1·1	2	467·9	1·3	468·0 H. 2·1
	468·7	2·5	5									470·0 H. thin
He 471·3	471·7	thin	1	471·8	3·0	1	471·8	4·0	6	472·0	4·2	472·1 H. 2·0
	482·4	1·2	2									
Hβ	486·1	3·5	10	486·1	3·0	9	486·1	2·7	1	486·1	2·9	486·1 H. 2·7
He 492·2	491·9	3·4	Prism H	?			?			495·8	2·3	495·8 H. 3·0
He 501·6	501·7	3·2		?			?			500·7	3·0	500·7 H. 3·0
	506·6	thin										
C 516·5	516·7	3·9										
	531·0	2·2										
	542·2	3·4										
	547·5	thin										
	553·2	2 9										
	558·1	1·7										

* Huggins. In Watts' Index.
† Very feeble. Other bands can be seen but not measured.

Structure of Bands—Bright Lines.

Band at		386·9.	396·9.		436·3.
On	Mar. 28.	Sept. 5, 11, Oct. 4, 6.	Sept. 5, 11, Oct. 4, 6.	Aug. 27.	Sept. 5.
By prism	T.	T.	T.	H.	T.
C. N. lines.					
		385·6 edge	395·6 edge	434·9 edge	434·9 edge
385·7	385·7 strongest	385·8 strongest	395·8 strongest	435·1 strongest	435·2 strongest
386·2	386·1	386·5	396·5	435·8	435·9
387·1		387·1	397·1	436·5	436·6
		387·8	397·8	437·3	437·4
388·3	388·3	388·2 edge	398·2	437·7 edge	437·8 edge

Band at	438·4.	457·2.	465·0.	467·9.	471·9.	
On	Mar. 3.	Mar. 12, 16.	Mar. 12, 17.	Aug. 27.	Aug. 27.	Sept. 5.
By prism	T.	T.	T.	T.	H.	T.
	436·1	456·1	461·9	467·2	469·8	470·2
	438·6	457·5	463·2	468·1	471·2 strongest	471·3 strongest
	440·4	458·9	464·4		472·4	472·3
	440·6		466·0			
			468·3			

The wave-lengths of spectrum I. and II. are corrected for velocity-displacements. Spectrum III. has given no indication of velocity-displacement.

Prism H is a compound direct prism on the 15-inch O.G. equatorial.

Prism T is a 4-inch objective prism on a 4-inch O.G. finder.

In column W the widths of the lines are given in spectral micro-millimetres.

In column *i* the strongest line on the plate is indicated by the number 10, no allowance being made for the sensibility curve of the photographic plate. The numbers therefore in different columns are not necessarily comparable. The intensities by prism H are not entered, on account of the great absorption effect of the dense flint glass. On this plate the strongest lines are 471·3 and 436·4.

TABLE VIII.

Dark-line Spectrum corrected for Velocity-displacement.

λ		On Dates.	
377·1	H₁	Mar. 3, 12.	Also κ, λ, μ, ν on Mar. 12.
379·8	Hθ		All to Mar. 12 inclusive.
381·6		,, 12.	Very clear.
383·6	Hη		All to Mar. 21 inclusive.
386·7		,, 12.	Clear.

λ		On Dates.	
388·9	Hζ		All to Mar. 21 inclusive.
389·5		Mar. 17.	Very clear fine line.
390·7		„ 17.	
391·9		„ 17.	
397·0	Hε		All dates to Mar. 21 inclusive.
399 6		„ 17.	
406·9		„ 12, 17, 20, 27.	Broad.
410·2	Hδ		All dates to Mar. 21 inclusive.
421·6		„ 12.	
434·1	Hγ		All dates to Mar. 21 inclusive.
438·5		„ 17.	Edge of Hγ.
459 3		„ 17.	Very fine, not strong.
461·4		„ 12, 17.	May be only continuous spectrum.
486·1	Hβ		All up to Mar. 21 inclusive.

Stonyhurst College Observatory:
1901 *October* 10.

Observations of Nova Persei. By J. E. Gore, M.R.I.A.

I first saw this remarkable object on the evening of 1901 February 22, at 11.40 G.M.T., before I had heard of its discovery elsewhere. It was then much brighter than *α Persei* and seemed to me about equal to *Pollux*, or nearly first magnitude. I have since observed it on every available opportunity, and the following are all my observations to end of 1901 November. The observations were at first made with the naked eye, and afterwards, when the star became fainter, with a binocular.

The following are the comparison stars used in estimating the magnitude of the *Nova*. The magnitudes of the comparison stars are those given in the Revision of the Harvard Photometry. The estimates were made by the method of Argelander :—

Comparison Stars for Nova Persei.

Star.	Mag. Revision of H.P.	Star.	Mag. Revision of H.P.
Capella	0·24	32 (*l*) Persei	5·13
Pollux	1·25	36 Persei	5·27
α Persei	1·85	30 Persei	5·37
β Persei	2·31	(*b*) = D.M. + 44°, 734...	6·50
ε Persei	2 88	(*k*) = D.M. + 44°, 757	6·82
δ Persei	3·11	„ 759	
ν Persei	3·90	(*f*) = D.M. + 43°, 730...	6·91
κ Persei	4·07		

Observations of Nova Persei.

Date 1901.	Greenwich M.T. h m	Estimated Mag.	Notes.
Feb. 22	11 40	1·25	A great new star in Perseus between β Persei and δ Persei; preceding, a little north of ν Persei. Much brighter than α Persei and about equal Pollux.
23	11 25	...	Star still very bright but only seen through passing clouds; magnitude uncertain—seems at least first magnitude.
24	10 45	0·24	Nova seen between clouds; seems fully equal to Capella! Very bright; white with tinge of yellow.
26	10 55	1·05	Nova seen through intervals between fleecy clouds; seems much fainter; about one magnitude below Capella and one magnitude above α Persei; strong moonlight.
27	11 45	1·73	Nova about 1 step brighter than α Persei, much fainter than last night; Nova about same colour as Capella, more reddish than α Persei. Nova evidently fading rapidly. About 4 steps brighter than Algol. (N.B.—Algol *not* near a minimum.) Strong moonlight, but stars quite clear and easily observed.
Mar. 1	7 40	2·0	Nova about 1 "step" below α Persei, but not much superior to Algol; clear sky in vicinity of Nova; strong moonlight.
	10 38	2·13	Nova about 2 steps less than α Persei.
2	9 10	...	Nova about same brightness as last night but seen through fleecy clouds; estimate a little uncertain; strong moonlight.
	10 5	2·08	Nova 1½ step below α Persei, and 1½ step above Algol; sky clear round these stars. Nova more yellowish than α Persei. Seemed to twinkle a little more than α Persei.
3	8 30	2·45	Nova 3½ steps less than α Persei, and 1 step less than Algol; very clear sky; strong moonlight. Nova has still an orange tinge.
7	7 5	2·88	Nova about equal to ε Persei; but strong twilight, observation a little doubtful, but not very.
	9 38	2·82	Nova = ε Persei, and Nova 2½ δ Persei; sky clear in vicinity of Nova; Moon low.
8	11 35	3·11	Nova 2 steps below ε Persei and about equal to δ Persei; pretty clear in vicinity; moonlight.
12	10 15	3·31	δ Persei 2 Nova 6 ν; clear sky, no Moon.
13	10 20	...	Nova seems a little fainter than last night, but some clouds about; observation doubtful.
18	11 0	3·90	Nova equal to ν Persei and considerably less than δ Persei; clear sky between passing clouds; no Moon.

Date 1901.	Greenwich M.T. h m	Estimated Mag.	Notes.
Mar. 21	8 55	4·0	Nova about 1 step less than ν Persei, but considerably brighter than 32 (l) Persei with naked eye. Slightly reddish with binocular; might be described as "claret" tint; very clear sky but phosphorescent; no Moon; cold easterly wind.
23	8 15	3·85	Nova 1 step *brighter* than ν Persei and 2 steps brighter than κ Persei with naked eye and binocular; sky clear from clouds, but air very hazy; crescent Moon.
25	12 5	5·22	(32) 2 (Nova) 3 (30 Persei), with binocular; clear sky, but hazy; moonlight. Nova much fainter than ν or κ Persei.
26	8 40	4·05	Nova 1 step less than ν Persei, with naked eye and binocular; much brighter than 32 Persei. 32 rather more than half a magnitude above 30. Clear sky; moonlight.
	10 55	4·18	Nova 2 steps below ν Persei; sky clear in vicinity of Nova.
27	8 55	3·90	Nova *much* brighter than 32 Persei and distinctly brighter than last night; about equal to ν Persei, and (Nova) 1 (κ Persei) with naked eye and binocular; clear sky; strong moonlight.
28	9 5	5·13	Nova = 32 (l) Persei, and (Nova) 3 (36 Persei) with binocular; clear sky; strong moonlight; very cold; Nova much fainter than ν and κ Persei.
29	10 25	4·73	Nova considerably less than ν Persei, but 3 steps brighter than 32 (l) Persei. Seen between passing clouds; strong moonlight.
Apr. 1	9 5	4·35	(ν Persei) 3 (Nova) 5 (32 Persei); clear sky; strong moonlight. Nova visible to naked eye.
6	9 10	5·32	(32 Persei) 4 (Nova) 1 (30 Persei), between clouds; estimate uncertain, but Nova certainly below 32; much fainter than ν and κ Persei.
7	8 40	5·37	Nova equal to 30 Persei and distinctly below 32; very clear sky; no moonlight.
	9 50	5·50	Nova *just* visible to naked eye; 1 step less than 30 Persei; a faint star compared with ν and κ Persei.
8	10 0	4·5 ±	Nova seen in a very hazy sky; seems brighter than last night, but less than ν Persei; about 4·5 mag., but observation uncertain.
	10 25	4·5 ±	Nova again seen; about the same as above.
9	8 50	4·59	(ν Persei) 4 (Nova) 3 (32 Persei), and ν 4 Nova 4 (36 Persei); clear sky; no Moon; Nova visible to naked eye.
	9 45	4·61	ν 4 (Nova) 2 (32 Persei), and ν 4 Nova 5 (36 Persei); very clear sky; Nova very visible to naked eye.
11	11 50	5·37	Nova = 30 Persei, and distinctly below 32; clear sky; no Moon; Nova low down, but observation certain.

Date 1901.	Greenwich M.T. h m	Estimated Mag.	Notes.
Apr. 13	9 15	4·25	ν 2 (Nova) 5 (32 Persei); hazy sky, but observation fairly good; no Moon; Nova visible to naked eye.
14	10 ?	5·44	Nova = 30 Persei, or perhaps 1 step less; *very* clear sky; no Moon.
15	10 15	5·37	Nova = 30 Persei; seen between clouds.
16	9 1	5·50	(30 Persei) 1 (Nova), and Nova considerably less than 32 Persei; clear sky, but hazy and rather bright.
	9 45	5·37	Nova about equal to 30 Persei; very little difference between the two.
18	9 20	4·39	(ν Persei) 4 (Nova) 6 (32 Persei); hazy sky, but observation pretty certain. Nova again increased in brightness; visible to naked eye.
19	8 55	5·33	(32) 5 (Nova) 1 (30 Persei); sky clear, but rather hazy; no Moon; sky rather bright; Nova not visible to naked eye at $9^h\ 30^m$.
20	9 7	5·50	Nova about 1 step below 30 Persei, but sky very hazy, and thin clouds about; observation uncertain.
21	10 2	5·37?	Nova about equal to 30 Persei, but very hazy sky; observation uncertain.
25	9 55	...	Nova scarcely visible through haze, but seems to be faint; $5\frac{1}{2}$ mag. or less.
	10 15	$5\frac{1}{2}$	
27	9 13	4·48	(ν Persei) 4 (Nova) $4\frac{1}{2}$ (32 Persei); pretty clear sky; moonlight.
28	9 45	5·30	Nova faint, about equal to 30 Persei, or 1 step brighter; moonlight and slight haze.
30	9 37	5·37?	Nova faint in the moonlight, and haze and about equal to 30 Persei, but observation uncertain; scarcely visible in binocular.
May 1	9 37	4·5?	Nova barely visible through clouds of smoke, but it seems up again; perhaps 4·5 mag.; less than ν Persei.
	10 20	4·56	Nova brighter than 32, but less than ν Persei; moonlight and haze.
5	1 25	5·50	Nova 1 step below 30 Persei; clear sky; moonlight; star low but fairly well seen; faint, *much* fainter than ν Persei.
6	10 35	5·5?	Some clouds. Nova seems still faint, about $5\frac{1}{2}$ mag., but uncertain.
July 31	12 35	5·87	(30 Persei) 4 (Nova) 5 *b*; clear sky; strong moonlight.
Aug. 6	10 10	5·88	(30 Persei) 5 (Nova) 6 *b*; clear sky; good observation.
8	10 20	5·75	(30) 3 Nova 6 *b*; sky clear but hazy; good observation.

Date 1901.	Greenwich M.T. h m	Estimated Mag.	Notes.
Aug. 10	10 25	6·08	(30) 5 (Nova) 3 *b*; clear sky; no Moon; good observation.
15	10 20	6·12	(30) 6 (Nova) 3 *b*; clear sky; no Moon.
17	10 25	6·05	(30) 6 (Nova) 4 *b*; clear sky; no Moon.
18	10 20	6·12	(30) 6 (Nova) 3 *b*; clear sky; no Moon.
19	10 20	6·12	(30) 6 (Nova) 3 *b*; pretty clear sky, but unsteady air.
20	10 10	6·08	(30) 5 (Nova) 3 *b*; clear sky.
21	10 15	6·21	(30) 6 (Nova) 2 *b*; clear sky; moonlight.
22	10 20	6·25	(30) 7 (Nova) 2 *b*; clear sky but hazy.
24	10 43	6·45	Nova about equal to *b*; hazy sky and moonlight.
25	11 0	6·22	Nova 2 *b*; seen between drifting clouds.
26	12 10	6·22	Nova 2 *b*; clear sky; moonlight.
27	10 40	6·22	Nova 2 *b*; pretty clear; moonlight.
Sept. 4	10 59	6·22	Nova 2 *b*; clear; moonlight.
15	9 25	6·50	Nova = *b*; night hazy; no Moon.
16	9 25	6·22	Nova 2 *b*; pretty clear; no Moon.
	9 58	6·50	Nova = *b*.
17	8 50	6·50	Nova = *b*; clear; no Moon.
20	8 36	6·50	Nova = *b*; clear sky; moonlight.
23	8 40	6·50	Nova = *b*; hazy sky; moonlight.
24	8 49	6·50	Nova = *b*; clear sky; moonlight.
Oct. 2	8 7	6·50	Nova = *b*; clear; no Moon.
4	8 5	6·50	Nova = *b*; clear but hazy.
9	8 45	6·46	Nova 5 *f* and Nova 3 κ; hazy
18	6 55	6·46	Same as last observation.
19	7 25	6·65	Nova 3 *f* and Nova = κ; clear; crescent Moon.
31	7 35	6·80	Nova 2 *f* and κ 1 Nova; clear sky.
	8 0	6·65	Nova 3 *f* and Nova = κ; clear, but a little hazy.
Nov. 14	6 47	6·70	Nova 2 *f*; hazy sky.
16	6 50	6·86	κ 1, Nova 1 *f*; rather hazy.

The Observed Motion and Duration of the Radiant Point of the Perseids. By W. F. Denning.

In recent years a considerable number of observations have been made of the great display of *Perseids* in July and August, and the time seems to have arrived when the results may be usefully summarised. The writer called attention to the motion of the radiant in 1877 August, and reobserved this peculiarity in 1878, 1880, 1885, 1886, 1887, and in several subsequent years. Mr. D. Booth at Leeds obtained some special observations in 1888 and 1891 in examination of this feature, and his figures closely accorded with those previously derived at Bristol (*Observatory*, vol. xi., p. 380).

In tracing the displacement of a radiant it is necessary to keep the observations for each night separate, so that the individual centres for a series of dates may be determined and compared. Before 1893 it appears to have been customary to combine the materials accumulated on several successive or bordering nights, and thus the radiant points, based on such collections, formed diffused positions giving little or no intimation of motion. The necessity of confining the reductions to shorter periods was, however, impressed upon observers, so that in and since the very favourable year 1893 the observations employed in the deduction of the *Perseid* radiant have usually been limited to a single night, and the places determined in this way have proved of much value as evidence in respect of the E.N.E. motion of the shower centre. In the summary which follows I have arranged the radiants observed at Bristol in and since 1874 according to the day of the month on which they were made, and in a separate table have given similar observations by others in and since 1893,* for comparison. It was thought essential to keep the two sets of positions distinct, inasmuch as the Bristol results, if incorporated with the rest, might have unduly influenced the mean values and the deductions based on them. In fact, it seemed safer to arrive at conclusions justified by independent testimony, and to show the degree of mutual corroboration existing between the results derived at Bristol and at other stations. On inspection of the tables this will be seen to be very satisfactory when the nature of the observations is considered. During the last ten years quite a large number of observers have distinguished and followed, as far as conditions permitted, the easterly drift of the radiant, and the rate and direction of the movement have been pretty accurately assigned. As an observational fact this motion cannot be questioned. The writer has long regarded it as one of the most palpable, as well as

* An exception has, however, been made in regard to Mr. Booth's results obtained in 1888 and 1891, as he fixed the place of the radiant from observations on single nights.

one of the most certain, features he has ever noticed in this field of observation. And this trait in the visible character of the *Perseids* is one which appears to be in significant harmony with theory.

Judging from the remarkable increase in meteoric observers in recent years there seems every reason to suppose that the *Perseid* shower (offering as it does a rich display, appearing regularly at the most congenial season of the year) will be more critically studied, and that its radiant point will often be traced as it passes from the southern stars of *Cassiopeia* along the northern borders of *Perseus* into *Camelopardalis*. No doubt this transitory character of the centre is not a feature which is apparent only in the behaviour of the *Perseids*. It is similarly exhibited by the April *Lyrids* and probably by certain other systems, but they are displayed so briefly and often so feebly that it is difficult to glean a sufficient number of well-observed meteors to fix their radiants accurately on nights near the limits of their visibility. On the other hand, a movable radiant is not a common feature, for certain well-defined showers, among which may be instanced the October *Orionids*, show stationary radiants. These peculiarities require further investigation in regard to many of the principal streams. It seems desirable that the *Quadrantids* or *Boötids* of January, the *Lyrids* of April, the *Aquarids* of May and July, the *Orionids* of October, the *Leonids* and *Andromedids* of November, and the *Geminids* of December should all be perseveringly watched in future years with particular regard to their visible durations and to the mobile or fixed radiants which they individually display.

The abbreviations in the list of *Perseid* radiants determined by various observers are :—

E. M. A. ...	...	E. M. Antoniadi, Juvisy.
W. E. B. ...	...	W. E. Besley, London, S.W.
E. R. B. ...	...	E. R. Blakeley, Dewsbury.
D. B. ...	...	D. Booth, Leeds.
J. H. B. ...	...	J. H. Bridger, Farnborough.
H. C. ...	...	H. Corder, Bridgwater.
W. D. ...	...	W. Doberck, Hong Kong.
J. A. H. ...	...	J. A. Hardcastle, Littlemore, Oxon.
A. S. H. ...	...	A. S. Herschel, Slough.
W. H. M.	...	W. H. Milligan, Belfast.
C. D. P. ...	...	C. D. Perrine, Lick Observatory.
T. E. R. P.	...	T. E. R. Phillips, Yeovil.
H. J. T. ...	...	H. J. Townshend, Leeds.

The observations at Bristol were made at Bishopston, a suburb about two miles north of the central part of the city. During the years from 1869 to 1901 inclusive I observed 8,002 shooting stars on the forty-three nights between July 11 and August 22 inclusive, and these included 2,856 *Perseids*.

With reference to the theoretical conclusions on the displacement of apparent radiant points there is a valuable paper in *Monthly Notices*, vol. lii., pp. 341–54, by the late Joseph Kleiber. Mathematical deductions are here compared with some observational results, and in the case of the *Perseids* they present an excellent accordance. Mr. Kleiber gives the computed place of the radiant on July 8 as 9°+46°, August 8 41°·5+57°·3, August 9 42°·9+57°·6, August 10 44°·2+57°·9, and August 16 54°+59°. Le Verrier first pointed out that theoretically such a displacement must occur, and in 1859 some visible indications of it were recognised by Professor A. C. Twining in America, but the observations were too meagre and inaccurate to prove anything conclusively.

In the lists of radiants I have included those of several very early or late *Perseids* whose real paths were determined from two or more observations, as the places afford a useful corroboration of the radiant positions of the shower at times when it has been but scantily recorded. The real paths and radiants of several hundreds of *Perseids* have been found for dates between August 1 and 14, but it has not been thought desirable to include these, as they were nearly all recorded on August 9, 10, or 11, when the situation of the radiant has been sufficiently well indicated from other observations. The letters "F" and "SS" refer to radiants deduced from duplicate observations of Fireballs and Shooting Stars respectively.

Radiant Points of the Perseids observed by W. F. D.

		α	δ	ℓ's
		°	°	
1877–8	July 8–13	11	+48	10
1876–7	July 18	17	+50	4
1900	19	17	+50	SS
1887		19	+51	4
1901	21	23	+52	5
1887	22	25	+52	5
1887	23	25	+52	4
1900		24	+52	SS
1900–1 &c.	24	23	+52	5
1900–1	25	22	+52	5
1878	26	30	+53	5
1887	27	29	+54	5
1883	28	27	+55	10
1887		30	+55	10
1878		32	+53	10
1879		32	+53	9
1887	29	31	+54½	10
1878	July 30	32	+53	12
1898		23	+53	SS
1900		30	+52	F
1900		31	+54	10
1899	July 29–Aug. 2	34	+54	8
1878	July 31	32	+53	20
1877		35	+54	11
1878	Aug. 1	32	+54	10
1887		36	+56	4
1897	1–2	36	+56	13
1886	2	33	+55	12
1888		35	+54	14
1881		39	+55	14
1877	3	39	+55	7
1886	4	37	+57	12
1877		41	+56	6

			α	δ	↙'s
1893	Aug.	5	39	+55	4
1888			42	+57	11
1896		6	42	+56	7
1887			42	+55	5
1899			40	+55	6
1877		7	40	+56	7
1899			41	+58	10
1880			41	+55	14
1887			43	+56	5
1895			41	+57	5
1880		8	41	+55	23
1893			41	+56	12
1888			42	+57	20
1887			43	+56	5
1893		9	43	+57	20
1880			44	+55	71
1899			44	+57	26
1879			46	+58	38
1874		10	44	+58½	252
1876			43	+59	43
1877			43	+58	285
1878			42½	+54	106
			44	+59	
1880			45	+57	41
1882			43	+57	8
1884			44	+59	16
1886			44	+57	122
1887			42½	+57½	22
1893			45	+57	14
1895			45	+55	17
1896			45	+57	69
1899			44	+57	72
1901			44	+58	55
1880		11	48	+57	43
1882	Aug.	11	46	+57	45
1886			47	+57	15
1887			45	+57½	16
1895			44	+58	7
1899			46	+57	69
1901			45	+58	49
1898			46	+58	106
1880		12	48	+57	19
1877			50	+55	14
1899			48	+5	43
1893			48	+58	7
1896			46	+57	7
1880		13	49½	+57½	7
1888			52	+57	13
1885			51	+58	6
1899			49	+58	10
1893			48	+58	8
1899		14	50	+56	12
1893			49	+57	7
1887			53	+57	8
1901		15	51	+58	6
1901			56	+58	SS
1901			52	+53	F
1884–5		15–16	53	+59	5
1893		16	52	+57	4
1899			53	+57	7
1900			54	+58	5
1901			53	+58	5
1885–91		17	54	+60	5
1893–1901		18	55	+59	11
1884–1901		19	57	+59	5
1901		20	57	+58½	6
1901		21	61	+59	7
1900–1		22–3	59	+59	5

Radiant Points of Perseids determined by various Observers.

			α	δ	↙'s	
1900	July	19	15°	+49°	SS	A.S.H.
1897		22–7	23	+49	17	A.S.H.
1900		23	23	+51	5	W.E.B.
1900	July	23	20°	+51°	SS	A.S.H.
1900			27	+54	SS	A.S.H.
1897		23–4	24	+50	5	A.S.H.

		α	δ		
		°	°		
1900	July 24	25	+52½	7	W.E.B.
1897	25	22	+52	4	H.C.
1888	26	20	+55	5	D.B.
1891	27	28	+58½	7	D.B.
1898	29	31	+54	5	E.R.B.
1897	30	37	+53	4	H.C.
1900		30	+54	4	E.M.A.
1900	July 30–Aug. 1	33	+54½	4	J.H.B.
1897	July 30–Aug. 2	27	+53	24	A.S.H.
1897	Aug. 1	33	+56	4	E.R.B.
1899		30	+54½	5	J.H.B.
1895	2	35	+55	16	E.R.B.
1897	3	32½	+57	6	W.E.B.
1901		35	+56	...	E.M.A.
1895	3–4	43	+57	6	W.H.M.
1895	4	38	+54	5	E.R.B.
1891		39	+57	11	D.B.
1893	5	39	+54	4	E.R.B.
1896		37	+57	10	W.H.M.
1897	2–8	36	+55	17	A.S.H.
1894	6	38	+56	15	E.R.B.
1894		45	+57	8	W.H.M.
1894		45	+57	15	H.C.
1895	7	39	+53	11	E.R.B.
1895		40	+56	7	H.C.
1900		39	+54	5	J.H.B.
1888	8	42	+57½	21	D.B.
1893		42	+55	21	E.R.B.
1894		47	+57	4	H.C.
1893	9	44	+55	9	E.R.B.
1894		41¼	+54½	...	C.D.P.
1894		42	+56	17	E.R.B.
1893		43	+57	15	D.B.
1895		43	+57	23	H.C.
1896		40	+58	22	W.H.M.
1897		42	+56	21	A.S.H.
1897		51	+57	19	A.S.H.
1897		45	+57	17	H.C.
1897	Aug. 9	43½	+57½	71	W.E.B.
1898		42	+55½	10	J.H.B.
1899		41	+55½	8	J.H.B.
1899		44½	+57	7	A.K.
1901		41	+57	...	E.M.A.
1901		40	+55	4	J.H.B.
1893	10	44	+56	50	E.R.B.
1893		45	+57	17	W.H.M.
1893		44	+57½	100	H.C.
1894		46	+55	...	C.D.P.
1894		42	+56	49	E.R.B.
1894		45	+51	15	H.J.T.
1896		46	+57	11	J.A.H.
1896		43	+58	20	E.R.B.
1896		47½	+58	...	D.B.
1896		47	+58	30	H.C.
1898		43	+55½	16	J.H.B.
1898		43	+59	11	H.C.
1898		45	+55	...	T.E.R.P.
1898		43	+53	...	H.J.T.
1899		43	+56	12	J.H.B.
1899		45	+57	29	A.K.
1899		45	+58	54	W.E.B.
1899		45	+56	84	E.M.A.
1901		43	+56½	7	J.H.B.
1893	11	44½	+57½	23	W.D.
1894		44	+65	...	C.D.P.
1895		45	+56	13	E.R.B.
1895		43	+58	...	A.S.H.
1895		43½	+58	72	H.C.
1896		45	+55	43	E.R.B.
1898		45	+58	40	W.E.B.
1898		45	+56	13	J.H.B.
1898		49	+58	13	H.C.
1898		46	+58	...	T.E.R.P.
1898		46	+56	29	H.J.T.
1898		45	+58	30	E.R.B.
1899		45	+57	18	J.H.B.
1899		45	+57	8	W.E.B.

			α	δ	↙'s	
1899	Aug	11	46+57	17	A.K.
1899			46½+56	116	E.M.A.
1900			43+56½	6	J.H.B.
1901			46½+57	14	A.K.
1901			44½+56½	9	J.H.B.
1893		12	44+56	26	E.R.B.
1896			48+57	6	E.R.B.
1896			48+60	30	H.C.
1899			46+56½	10	J.H.B.
1899			46+57	6	E.M.A.
1899			46½+58	7	A.K.
1899			48+58	15	W.E.B.
1900			48+58	12	A.K.
1901			47+58	13	A.K.
1901			44+57	...	E.M.A.
1888		13	51½+56	17	D.B.
1895			51½+56½	14	H.C.
1896			50+59	10	E.R.B.
1899			48+55	15	E.M.A.
1899			49+57	5	A.K.
1899			49+58	10	E.M.A.
1899		13–14	49+58	8	A.K.
1888		14	55+59½	5	D.B.
1891	Aug.	14	56+58½	8	D.B.
1893			49+55	10	E.R.B.
1893			54+59	...	H.C.
1895			51+58	6	E.R.B.
1896			51+59	24	E.R.B.
1899			50+58	5	W.E.B.
1900			50+56	5	E.M.A.
1891		15	58½+59½	6	D.B.
1893			51½+59	...	E.R.B.
1893			55+57	5	H.C.
1896			50+58	8	W.H.M.
1901			51+58	4	A.K.
1901			48+58	5	J.H.B.
1901			53+58	...	E.M.A.
1901			54+53	F	A.S.H.
1901			58+58	SS	A.S.H.
1893		17	58+62	7	E.R.B.
1893		18	54+62	...	E.R.B.
1893			51+56	11	H.C.
1901		19	53+58	...	E.M.A.
1893		21	55+57	3	W.H.M.
1893			55+65	6	

Mean Radiant Points of Perseids.

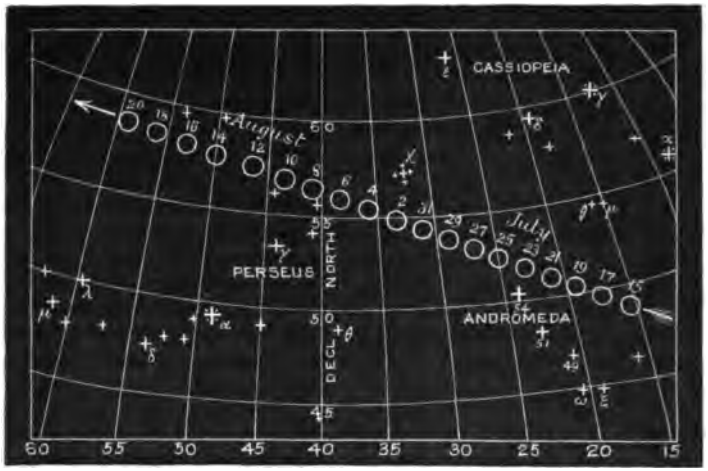
	W.F.D. α	W.F.D. δ	Radiants.	Other Observers. α	Other Observers. δ	Radiants.	Mean of all. α	Mean of all. δ	Radiants.
July 8–13	11·0	+48·0	1	...	...	...	11·0	+48·0	1
18	17·0	+50·0	1	...	...	...	17·0	+50·0	1
19	18·0	+50·5	2	15·0	+49·0	1	17·0	+50·0	3
20	...	...	...	...	...	...	...	...	...
21	23·0	+52·0	1	...	...	...	23·0	+52·0	1
22	25·0	+52·0	1	...	...	...	25·0	+52·0	1
23	24·5	+52·0	2	23·3	+52·0	3	23·8	+52·0	5
24	23·0	+52·0	1	25·0	+52·5	1	24·0	+52·2	2
25	22·0	+52·0	1	22·0	+52·0	1	22·0	+52·0	2
26	30·0	+53·0	1	20·0	+55·0	1	25·0	+54·0	2
27	29·0	+54·0	1	28·0	+58·5	1	28·5	+56·3	2
28	30·2	+54·0	4	...	...	...	30·2	+54·0	4
29	31·0	+54·5	1	31·0	+54·0	1	31·0	+54·2	2

		W.F.D. α ° δ °	Radiants.	Other Observers. ° °	Radiants.	Mean of all. α ° δ °	Radiants.
July	30	29·0 + 53·0	4	33·5 + 53·5	2	30·5 + 53·2	6
	31	33·7 + 53·7	3	33·0 + 54·5	1	33·5 + 53·9	4
Aug.	1	34·0 + 55·0	2	31·5 + 55·3	2	32·8 + 55·1	4
	2	35·7 + 54·7	3	35·0 + 55·0	1	35·5 + 54·7	4
	3	39·0 + 55·0	1	33·7 + 56·5	2	35·5 + 56·0	3
	4	39·0 + 56·5	2	38·5 + 55·5	2	38·8 + 56·0	4
	5	40·5 + 56·0	2	37·3 + 55·3	3	38·6 + 55·6	5
	6	41·3 + 55·3	3	42·7 + 56·7	3	42·0 + 56·0	6
	7	41·2 + 56·4	5	39·3 + 54·3	3	40·5 + 55·6	8
	8	41·7 + 56·0	4	43·7 + 56·5	3	42·6 + 56·2	7
	9	44·2 + 56·7	4	42·9 + 56·3	15	43·2 + 56·4	19
	10	43·9 + 57·3	15	44·4 + 56·3	19	44·2 + 56·8	34
	11	45·9 + 57·4	8	45·1 + 57·4	19	45·3 + 57·4	27
	12	48·0 + 56·8	5	46·5 + 57·5	10	47·0 + 57·3	15
	13	49·9 + 57·7	5	49·8 + 56·9	6	49·9 + 57·3	11
	14	50·7 + 56·7	3	52·0 + 57·9	8	51·6 + 57·5	11
	15	53·0 + 56·3	3	53·2 + 57·6	9	53·2 + 57·3	12
	16	53·0 + 57·5	4	... ...	...	53·0 + 57·5	4
	17	54·0 + 60·0	1	58·0 + 62·0	1	56·0 + 61·0	2
	18	55·0 + 59·0	1	52·5 + 59·0	2	53·3 + 59·0	3
	19	57·0 + 59·0	1	53·0 + 58·0	1	55·0 + 58·5	2
	20	57·0 + 58·5	1	... ...	...	57·0 + 58·5	1
	21	61·0 + 59·0	1	55·0 + 61·0	2	57·0 + 60·3	3
	22–3	59·0 + 59·0	1	... ...	...	59·0 + 59·0	1
			99		123		222

It will be seen from the mean positions of the radiant that the R.A. does not exhibit a regular diurnal increase, but that some marked irregularities are apparent. These are obviously due to errors of observation, which in certain cases have been large, and which, even in the most accurate results, have not been wholly eliminated. If the mean values for the radiant from all the observations are grouped into five-day periods the increase in the R.A. and N. Dec. becomes well defined, as follows:—

Period.	Mean Place of Radiant. α ° δ °	Number of Radiants.
July 18–22	20·5 + 51·0	6
23–27	24·7 + 53·3	13
28–Aug. 1	31·6 + 54·1	20
Aug. 2–6	38·1 + 55·7	22

Period.	Mean Place of Radiant. α	δ	Number of Radiants.
Aug. –11	43°·2	+56°·5	95
12–16	50°·9	+57°·4	53
–22	56°·2	+59°·4	12



Positions of the Perseid Radiant Point, July 15 to August 20.

From the whole of the observations I have drawn up the following ephemeris, but the figures are not intended to simply represent the curve deduced from them, certain corrections having been applied. The year 1900 not being Leap Year, and nearly all the materials having accumulated before that year, the result is that the position of the radiant will be about 1° less in R.A. in the immediate future than on the same date before 1900. In fact, the maximum displays of the shower will occur a day later, and be witnessed either on August 11 or 12. I have allowed for these effects, and also for the circumstance that my own observations and a certain proportion of the others required a small correction for precession. A few of the observed radiants included in the tables are undoubtedly erroneous, from their discordance with others of contemporary date, and all such positions should be excluded in attempts to derive reliable places for the shower.

It is to be hoped that observers will carefully test the degree of accuracy of the ephemeris, either by photographs of meteor trails or by very exact eye-observations, in future years. I think it quite possible that the radiant should be placed a little farther north, particularly at about the period of the maximum, for the presence of the stars γ and η *Persei* just south of the radiant must probably have exercised a slight influence in leading

observers to place the centre too far south. It is often found that when a bright or fairly conspicuous star is situated near a radiant the latter is apt to be assigned nearer to the star than the truth requires. The ephemeris gives the R.A. of the radiant as less than that indicated in the similar table published in *Memoirs*, vol. liii., p. 210; but this is to be chiefly ascribed to the alteration rendered necessary by the absence of leap year in 1900, and moreover the present ephemeris has been independently formed from more extensive materials than could possibly be employed in the previous case:

Ephemeris of the Perseid Radiant Point.

	α	δ		α	δ
	°	°		°	°
July 15	15·3	+48·9	Aug. 3	35·1	+55·3
16	16·2	+49·3	4	36·4	+55·5
17	17·1	+49·7	5	37·6	+55·7
18	18·0	+50·1	6	38·9	+56·0
19	18·9	+50·5	7	40·2	+56·2
20	19·8	+50·8	8	41·5	+56·5
21	20·8	+51·1	9	42·9	+56·7
22	21·8	+51·5	10	44·3	+56·9
23	22·8	+51·8	11	45·7	+57·1
24	23·8	+52·2	12	47·1	+57·3
25	24·9	+52·5	13	48·5	+57·5
26	26·0	+52·8	14	50·0	+57·7
27	27·1	+53·2	15	51·4	+57·8
28	28·2	+53·5	16	52·9	+58·0
29	29·3	+53·8	17	54·4	+58·2
30	30·5	+54·1	18	55·9	+58·4
31	31·6	+54·4	19	57·4	+58·5
Aug. 1	32·7	+54·7	20	58·9	+58·7
2	33·9	+55·0			

Probably the display commences in a very feeble form before July 15, and is continued to a later date than August 20. In the third week of July the shower is, however, very liable to be confused with a radiant of swift, streak-leaving meteors directed from near γ *Andromedæ* (24°+43°); and in the third week of August it becomes apparently blended with a shower of *Camelopardids* (60°+59°).

Bishopston, Bristol: 1901 *November* 10.

Note on a Large Fireball. By W. F. Denning.

At $5^h\ 36^m$, soon after dark on the very clear frosty evening of December 4 last, a fireball of exceptional brilliancy was observed from various parts of the country. It gave a flash of dazzling intensity, illuminating the English Channel and South of England with a light stronger than that of the full Moon. The fireball had a bluish-green head, and along the more luminous section of its flight it projected a train or streak of orange-red material, which remained visible to the eye from a few seconds to five minutes according to the various estimations made by different persons.

The position of the train amongst the stars was carefully noted by several observers. Admiral Maclear at Chiddingfold, Surrey, found it to extend from $290\frac{1}{2}° + 11\frac{1}{2}°$ to $295\frac{1}{2}° + 5\frac{1}{2}°$, and Mr. G. F. Oldham, of Tunbridge Wells, Kent, says it was 7° or 8° long and placed midway between *o Herculis* and *χ Aquilæ*, and in a straight line with these stars and the planet *Venus*. The Rev. W. F. A. Ellison, of Dublin, saw the fireball as it flashed out in *Cetus*, low in the S.E., and the place of the lingering train was from $7° - 10°$ to $16° - 16°$. From these and some additional descriptions which I have compared the real path appears to have been as follows:

Height at beginning	...	91 miles over English Channel, 11 miles S. of Bridport, Dorset.
Height at ending ...	...	50 miles over English Channel, 15 miles S. of Needles, Isle of Wight.
Length of path ...	...	64 miles.
Approximate velocity	...	21 miles per second.
Earth point ...	...	37 miles S. of Brighton.
Height of streak ...	...	72 to 55 miles.
Length of streak ...	...	26 miles.
Radiant point ...	...	$263° + 36°$.

These results approximately represent a portion of the course. The whole of the luminous flight of this brilliant *Herculid* fireball may quite possibly have extended further, both at the beginning and end, but precise limits cannot be assigned, many of the observations being indefinite and some of them contradictory on this point.

Bishopston, Bristol: 1901 *December* 10.

Observation of the Leonid Meteors of 1901, *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

On the nights of November 14–15 and November 15–16 watch for meteors was maintained by four observers from midnight to 5 A.M., with the following results :—

Date. 1901.	Length of Watch.	Total Number of Meteors.	Number of Leonids.	Number of Leonids per Hour.
November 14–15	5 hours	66	46	9·2
„ 15–16	5 „	43	43	8·6

The night of November 13–14 was overcast and rainy, November 14–15 was cloudless and bright, and November 15–16 was partially foggy and cloudy. The number of Leonids observed each year since 1887 is given in the *Monthly Notices*, vol. lx., p. 163. Reference to this table shows that a much larger number of meteors was observed this year, though it should be remembered that the weather was rather more favourable this year than in most of the preceding years. These observations afford some evidence that this year the Earth passed through part of the meteor swarm denser than the average, and probably denser than in any of the years 1896 to 1900.

Royal Observatory, Greenwich:
1901 *December* 19.

The Leonids, 1901. *Observations made at the Radcliffe Observatory, Oxford.*

(*Communicated by the Radcliffe Observer.*)

During the night of November 13 the sky was occasionally watched for a possible shower of *Leonids*, but few meteors were seen.

On November 15 from 12^h to 15^h G.M.T. the sky was generally clear, but high driving fog passed across at times. Mr. McClellan, who watched at frequent intervals, saw only two meteors, viz. :—

G.M.T.
h m
14 40 1st magnitude; Leonid with train from μ Leonis towards 38 Lyncis.

14 42 Sporadic.

A special watch for meteors was commenced on the night of November 14, just before 13^h G.M.T., by Mr. Robinson. Except during a short break ($15^h\ 11^m$ to $15^h\ 23^m$ G.M.T.) the watch was continuous until 18^h G.M.T. The observer remarks :—

At first the constellation of *Leo* was only dimly visible in a low mist, which, however, became less dense later on. The sky was cloudless throughout, and stars to the 5th or 6th magnitude could be easily seen, except for small altitudes. About 17^h G.M.T., and a little earlier, a long band of diffused light about 10° in width was observed stretching from the eastern horizon towards and slightly beyond the six stars forming the "Sickle." The phenomenon—probably that of the zodiacal light—became more conspicuous later on, or just before dawn. Its position then lay along the ecliptic, enveloping *Spica* in E.S.E., across the constellations of *Virgo* and *Leo*, the brightest and broadest portion being over the horizon.

The *Leonids* presented the characteristic features observed in former years, being swift, and generally leaving luminous trails, visible for two or three seconds. The approximate G.M.T. for each meteor was recorded, and notes of magnitude, direction, velocity, and trails of the more important were taken. When the observer had fully identified the brighter stars in the neighbourhood of *Leo*, several of the more luminous tracks were charted. For this purpose a wand, held and adjusted across the trail or streak, enabled a reliable observation to be made of the direction of the flight of the meteor. Seven observed in this way give a radiant of small area near

R.A. $9^h\ 55^m\ 50^s$ or 148° 58′; Decl. +22° 47′. Epoch 1900.

Almost invariably the paths of the other *Leonids* when produced backwards along the wand crossed the same point within the "Sickle." A number of the brighter meteors started at a great distance (about 30°) from the radiant.

Other radiants were apparently active, but meteors from these were regarded as of secondary importance, and their paths were secured with only rough approximation.

A marked peculiarity was the intermittent frequency of the *Leonids*, several long quiescent intervals being followed by active miniature showers. This feature was also noticed here in 1898 or 1899.

The following notes of meteors were taken :—

No.	G.M.T. h m	
1	12 51	1st mag.; passed between β and γ Ursæ Maj.; trail; Leonid.
2	12 58	Above Sirius; no trail; rapid.
3–6	13 0 to 13 17	In this interval 4 meteors counted, two of which possibly Leonids. The last a short bright streak above Leo.
7	13 20	Leo towards zenith; swift; no streak.

No.	G.M.T. h m	
8	13 24	S.E. Sickle; streak.
9	13 25	Leo towards zenith; very swift.
10	13 26	Short; in Gemini.
11	13 30	Short; possibly Leonid.
12	13 30	Near Pollux, below Pleiades; long bright trail.
13	13 33	1st mag.; track recorded on chart (A).
14	13 38	N. and N.W.; swift; 4th mag.
15	13 50	Short; low down N.E.; small.
16	13 51	From zenith; sporadic.
17	13 55	Ursæ Maj. to zenith; 3rd mag.
18	14 0	Above Leo; sporadic; 4th mag.
19	14 4	Through Gemini; streak; 3rd mag.
20	14 4	Below Sirius; swift; streak; 1st mag.
21	14 10	Sickle through zenith; long streak; 1st mag.
22	14 17	Near Sirius; sporadic; short; 4th mag.
23	14 19	Between ζ and μ Leonis; short; 4th mag.
24	14 21	Below Sickle; sporadic.
25	14 21	Above Sickle; sporadic.
26	14 24	Streak; 3rd mag.; path recorded (B) on chart.
27	14 30	N.E.
28	14 36	Through pointers of Ursæ Maj. to below pole; streak; bright; swift.
29	14 38	Through or near Aldebaran.
30	14 39	Passed between β and γ Ursæ Maj.; Leonid.
31	14 46	Ursæ Maj., low; doubtful Leonid.
32	14 49	Slow sporadic from between δ and β Leonis to below Regulus; streak; 4th mag.
33	14 50	Zenith towards Coma Berenices; 3rd mag.
34	14 54	Castor and Pollux to Sickle; sporadic.
35	14 55	Præsepe to γ Leonis; sporadic.
36	14 58	Sickle to between θ and α Hydræ.
37	14 59	Bright, from zenith.
38	15 2	Near δ Leonis, from Sickle.
39	15 6	Just above λ Ursæ Maj. to δ Ursæ Min. Direction same as A in chart.
	15 11 to 15 24	Break in watch.
40	15 26	Around Leo; not Leonids.
41	15 26½	
42	15 27	

No.	G.M.T. h	m	
43	15	31	Canes Venat., through Coma Berenices; sporadic.
44	15	36	Leonid; through α Canum Venat., below η Ursæ Maj.; streak.
45	15	38	Leonid; slightly above θ Hydræ, to Argo; streak.
46	15	41	From midway between Regulus and θ Hydræ, to east of Argo; streak.
47	15	43	Passed between β and γ Ursæ Maj.; Leonid.
48	15	43	Towards Cassiopeia; swift; 1st mag.
49	15	45	λ and μ Ursæ Maj.; Leonid; streak.
50	15	45	Below Leo; Leonid; streak.
51	15	47	Coma Berenices and β Leonis; streak.
52	15	(49)	Sporadic; west of Leo.
53	15	50	Leonid; between Regulus and o Leonis.
54	15	54	Towards S.E., from the western sky.
55	15	57	Leo to east of α Hydræ; very swift; no trail.
56	16	0	Bright; streak; path recorded on chart (C).
57	16	0½	Probably Leonid.
58	16	4	N.E.; swift.
59	16	7	Through Procyon; bright streak; Leonid.
60	16	7	Leonid; faint.
61	16	9	Sporadic.
62	16	10	Through ι and κ Ursæ Maj.; bright.
63	16	10	ENE$^{\text{ly}}$ direction; bright.
64	16	21	NW$^{\text{ly}}$ direction; streak.
65	16	21	Streak.
66	16	21	Streak.
67	16	22	Streak; towards η Ursæ Majoris from Radiant.
68	16	22	Streak; towards Ursa Major from Radiant.
69	16	23	Towards Arcturus.
70	16	26	Radiant to α Ursæ Maj.; streak.
71	16	27½	1st mag.; sporadic; Ursa Maj.; N.E. of Arcturus; sinuous.
72	16	29	Leonid; streak, towards Castor.
73	16	31	Sporadic.
74	16	37	Streak; sporadic; Præsepe through ϵ Leonis.
75 76	16	42	Two short Leonids, the first near γ Leonis, the second below the Sickle.
77 78	16	46	Two from zenith to east; sporadic.
79 80	16	49	Two doubtful Leonids.
81	16	56	Streak; Radiant to east.

No.	G.M.T. h m	
82	16 56	Streak; Radiant to east.
83	16 56	Streak; charted (D).
84	17 0	Leonid; towards δ or β Leonis.
85	17 2	Low E.S.E.; possibly Leonid.
86	17 5	No streak; in Leo.
87	17 5	No streak; in Leo.
88	17 6	Short; Leo; no streak.
89	17 12	Short; in Leo.
90	17 14	East of Regulus; eastwards.
91	17 15	Below Sickle; sporadic.
92	17 19	Leonid; Virgo.
93	17 20	Sporadic; Hydra.
94	17 21	Streak.
95	17 21	Bright; rapid; low down.
96	17 22	Streak from Hydra; sporadic.
97	17 23	Leonid; near Regulus; streak.
98	17 29	Streak; Leonid; between Hydra and Præsepe.
99	17 33	Leonid; below Arcturus.
100	17 34	Bright streak; charted (E).
101	17 44	To zenith.
102	17 45	To east.
103	17 45	Streak to N.E.
104	17 53	Streak; Leonid.
105	17 53	Streak; Leonid; charted (F).
106	17 59½	Bright streak; charted (G).
	18 0	Watch relinquished; twilight increasing.

The positions of the seven charted paths were as follows:

Epoch 1880.

	R.A. h m	Dec. ° ′		R.A. h m	Dec. ° ′
(A) From	9 59	+32 30	To	10 11	+50 0
(B) „	9 6	+13 0	„	8 26	+ 6 0
(C) „	10 55	+30 15	„	12 0	+39 30
(D) „	9 53	+17 0	„	9 53	+ 5 0
(E) „	9 10	+16 45	„	8 0	+ 7 30
(F) „	9 37	+18 0	„	9 0	+ 5 0
(G) „	10 24	+23 0	„	12 1	+20 0

Radcliffe Observatory, Oxford:
1901 *December* 11.

Apparent Paucity of the Leonid Stream.
By the Rev. S. J. Johnson.

The morning of November 14 was densely clouded; that of the 15th clear and frosty, giving opportunity for observation, especially as the Moon was absent. A little watching soon showed that the shower, though existing, was very feeble at the time and far inferior to that of the *Perseids* last August. It was about equal in intensity to that which I witnessed on the morning of 1896 November 14. From 2^h to $2^h\ 45^m$ (morn.) on the 15th I observed three *Leonids*, the largest being at $2^h\ 42\frac{1}{2}^m$, about 10° beneath *Regulus*; also one non-*Leonid* across η.

From 4^h to 5^h (morn.) five *Leonids*, two of which equal bright first magnitude stars, one at $4^h 7^m$, just beneath 46 *Leon. Min.*, greenish. From about 161°+34° to 163°+36°; the other at $4^h\ 24^m$, started about 3° left of *Arcturus*. From 215°+21° to 220°+18°.

On the morning of the 16th the radiant was slightly more active. Still, the Earth could only have been passing through outlying portions of the shower. From $4^h\ 55^m$ to 6^h A.M. I noticed nine *Leonids*, all within the first thirty-five minutes.

At $4^h\ 55\frac{1}{4}^m$ (morn.) nearly equal *Jupiter*, green train. Just beneath β *Leonis*. 173°+16° to 180°+13°.

At $5^h\ 1\frac{1}{4}^m$ magnitude 1 train. From a point 7° above δ *Leonis* going towards 12 *Coma Beren.* 168°+27° to 180°+28°.

At $5^h\ 23\frac{1}{4}^m$ equal *Jupiter*. Between ϵ *Virginis* and *Arcturus*. 197°+21° to 207°+11°.

All the *Leonids* seen had momentary trains.

Place of observation, window facing eastern heavens with several obstructions.

Melplash Vicarage, Bridport:
Nov. 30.

The Leonids, 1901. By F. W. Henkel, B.A.

The weather having been better on the whole than is usual at this time of the year at Markree, there was an opportunity of observing any display of meteors should it occur, but nothing of any consequence was seen here on the nights of November 15 and 16, which were clear for the most part. Being myself in England at the time, in the neighbourhood of Epping Forest, I made a watch from about 11 P.M. till towards daylight on the night of the 15th–16th, but saw nothing worthy of remark. The following night (Saturday) there was a dense fog, which prevented anything being seen of the sky at all. A gentleman whose occupation involves his being in London most part of the night, and who

watched from the neighbourhood of Dalston, told me that he saw no meteors at all.

It is evident from the reports to hand that there has not been any display this year of any consequence, though a few observers have been able to see a small number of meteors. It seems fairly certain that we are not likely to witness in this decade anything at all approaching the wonderful displays of 1833 and 1866, which have caused such an interest to attach itself to this swarm, but perhaps those of us who survive for another thirty years may be more fortunate.

Markree Observatory: 1901 *December* 10.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXII. JANUARY 10, 1902. NO. 3

Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

Ashton Charles Allen, 34 Kensington Palace Mansions, De Vere Gardens, W.;
John Hind Bell, *Nautical Almanac* Office, 3 Verulam Buildings, Gray's Inn, W.C.;
Walter Ernest Besley, 75 The Chase, Clapham Common, S.W.;
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Charles Summer Howe, Ph.D., Professor of Astronomy, Case Observatory, Cleveland, Ohio, U.S.A.;
William Gylby Hutchinson, Rock Lodge, Roker, Sunderland;
G. F. Johns, Perth Observatory, Western Australia;
James William Lowber, M.A., Sc.D., Ph.D., LL.D., F.R.G.S., F.R.Met.Soc. 113 East 18th Street, Austin, Texas, U.S.A.;
H. Krauss Nield, Thorold Grove, Sale, Cheshire;
Captain Michael Joseph O'Sullivan, 66 Fern Grove, Hartington Road, Sefton Park, Liverpool;
Charles Tallent Spencer, A.M.Inst.C.E., La Quinta, Lyon Road, Harrow; and
Rev. Charles Lakeman Tweedale, M.A., The Vicarage, Weston, near Ottley,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

John Waller Lawrence Child, Vernham, Merton Hall Road, Wimbledon (proposed by Col. E. E. Markwick) ;

José Comas Solá, S. Felipe, 29 S. Gervasio, Barcelona, Spain (proposed by A. Stanley Williams) ;

Rev. John Horsley Haslam, M.A. Cantab., Vicar of St. Saviour's, Denmark Park, S.E. (proposed by D. G. Simpson) ;

Joseph Lunt, B.Sc., F.I.C., Royal Observatory, Cape of Good Hope (proposed by Sir David Gill) ; and

Joges Chandra Ray, M.A., Professor of Physical Science, Cuttack, Bengal, India (proposed by U. Chandra Ghosh).

Seventy-six presents were announced as having been received since the last meeting, including amongst others :—

Galileo, Opere, Edizio Nazionale, vol. 11, presented by the Italian Government ; 22 Charts of the international photographic chart of the heavens, presented by the Paris Observatory ; Wedgwood Medallion of Sir Wm. Herschel by Flaxman, presented by Sir W. J. Herschel ; Photograph from a portrait of Galileo by Sustermans, presented by Sir W. Huggins.

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*The Attraction of the Himalaya Mountains upon the Plumb-line in India.** By Major S. G. Burrard, R.E., Superintendent of the Trigonometrical Survey of India.

1. In a paper read in 1895 before the Royal Society † the late General Walker advocated the employment of "groups" of astronomical stations for the purpose of eliminating the effects of local attraction at a central station. In the same paper he explained the preponderance of northerly deflections that prevails throughout India by the hypothesis that local attraction is producing a southerly deflection at Kalianpur, *the station of reference of the Indian Survey.*‡ In 1871 Archdeacon Pratt had come to the same conclusion ; in his "Figure of the Earth" he argues that an excess of density must exist near Kalianpur, for "the deflection

* For further details see Professional Papers of the Survey of India Department.

† *Phil. Trans.* clxxxvi. 745.

‡ No absolute deflection is known for any place ; all deflections are relative to that at Kalianpur. The term "northerly deflection" denotes a deflection "more northerly than the deflection at Kalianpur."

at Kalianpur," he writes, "is considerably south." Shortly after the issue of General Walker's paper in 1896, Sir David Gill's work on the Geodetic Survey of South Africa was published, in which the adoption of "groups" of astronomical stations was strongly recommended. In consequence of the opinions expressed by these eminent writers, and in full accord with their views, we decided in 1898 to determine the actual effect of local attraction at Kalianpur by means of a complete "group."

2. By the spring of 1899 astronomical observations for both latitude and azimuth had been taken at Kalianpur, and at eight adjacent stations, four being situated at an average distance of nine miles and four at an average distance of thirty-five miles from Kalianpur. A discussion of the results of the observations showed that local attraction was causing a *northerly* deflection at Kalianpur. This unexpected issue created a dilemma; either General Walker had been mistaken in advocating "groups," or his assumption of a southerly deflection at Kalianpur had been incorrect.

3. A classification of the results of the latitude observations discloses two remarkable facts: First, that two-thirds of the southerly deflections observed in India are situated within a narrow zone, running from east to west between the parallels of 24° and 26° approximately. Second, that large northerly deflections prevail from east to west between the parallels of 24° and 18° approximately.

4. I attached at first great significance to the fact that the parallel of 24°, along which approximately the direction of the deflection changes sign, happens to be the parallel of Kalianpur, the station of reference of the survey. I calculated the respective effects of the Himalayan mass and of the deficiency of matter in the Indian Ocean at twelve different stations, and found that if the Himalayas exercised their normal attraction on the plumb-line throughout India, and the deficiency of matter in the Indian Ocean exerted a northerly repulsive force, the sign of the deflections would change along the parallel of 24°. But this explanation of the observed phenomena could not be maintained; the results of the longitude arcs observed across India from coast to coast showed that the deficiency of matter in the Indian Ocean was wholly compensated by submarine strata of excessive density. If the effect of the Indian Ocean is compensated in the prime vertical it must be compensated also in the meridian.

5. After this first failure I undertook an investigation to see whether the change in the sign of the deflection could be due to errors of the ellipsoid of reference; but, though such errors would produce a change of sign along the parallel of the station of origin, the investigation showed that no considerable modification of the Clarke spheroid was possible.

6. The difficulty with which we are now confronted is this: it is clear that Himalayan attraction is *not* compensated so completely as Archdeacon Pratt believed, large deflections of

35″, 37″, 38″ having been met with in sub-Himalayan regions since the Archdeacon's death; but if Himalayan attraction is affecting the plumb-lines in India, the deflections north of latitude 24° should be more northerly than the deflection at Kalianpur, and the deflections south of latitude 24° should be less northerly. As has been explained above the observed deflections north of Kalianpur are southerly, and the observed deflections south of Kalianpur are northerly. (The deflections cannot be regarded as accidental or as due to "local attraction.")

7. To illustrate the observed phenomena the following table is given in which typical stations only have been entered. The meridian of 77° 30′ has been selected, but the same alternation of signs is observed on other meridians.

TABLE I.

Station.	Lat.	Observed deflection.	
Dehra Dun	... 30° 19′	−38″	Himalayan influences.
Kaliana ...	... 29 31	− 7	
Noh ...	... 27 51	0	Belt of southerly deflections.
Daiadhari	... 24 38	+ 1	
Kalianpur	... 24 7		station of reference.
Ladi ...	... 23 8	− 5	Belt of large northerly deflections.
Badgaon ...	... 20 44	− 8	
Damargida	... 18 3	− 3	
Cape Comorin	... 8 9	+ 2	

Under the Himalayas at Dehra Dun we find deflections of 38″; within sixty miles at Kaliana they dwindle to 7″; and in latitude 27° the deflections are southerly; south of Kalianpur at Ladi and Badgaon we meet with a succession of northerly deflections, which gradually become smaller as we proceed southwards to Cape Comorin.

8. The large deflections at Dehra Dun have hitherto not received the attention they deserve; they have been brushed aside with the remark, "At the foot of the Himalayas."

If Himalayan attraction is capable of producing a deflection of 38″ at Dehra Dun, its effects must be felt at Cape Comorin; on the other hand, if Himalayan attraction exercises no effect on plumb-lines south of Kaliana, it cannot produce a deflection of 38″ at Dehra Dun.

If a hemisphere of lead existed immediately north of Dehra Dun it might produce a large deflection there, and yet exercise no appreciable effect at Kaliana. But in the case of mountains—and the Himalayas are no exception—the vertical dimension is always small, and the change in elevation always gradual, and no overwhelming excess of matter can exist in the immediate

vicinity of a station situated even at their foot. In the *Philosophical Transactions of the Royal Society*, vol. 186, p. 803, General Walker wrote:—"It is thus evident that the effect of the attraction of mountain masses on the plumb-line, which may be very large in the immediate vicinity of the mountains, will be reduced at a distance in greater proportion than is assigned by an incomplete application of the law of gravitation, because of the deficiency in the density of the strata under the mountains, which has not hitherto been allowed for. Eventually a point must be reached at which the positive attraction of the matter above will be cancelled by the negative attraction of the deficiency below, and then the mountain masses will have no influence on the plumb-line."

When, however, one comes to apply in practice the theory propounded in this extract, one finds that if the Himalayas are compensated by underlying deficiencies of matter, the compensating cause will affect the plumb-lines at *both near and distant* stations.

9. I have calculated the effect of the attraction of the Himalayan mass at five stations on the meridian of 77° 30′, viz. Dehra Dun, Kaliana, Kalianpur, Damargida, and Cape Comorin, and have interpolated its effects at other stations from a plotted curve. The results are as follows :—

TABLE II.

Station.	Lat.	Calculated deflection due to—			Differential deflection from Kalianpur.
		Himalayan ranges.	Tibetan Plateau.	Total.	
	° ′	″	″	″	″
Dehra Dun ...	30 19	19	53	72	−54
Kaliana	29 31	2	34	36	−18
Noh	27 51	1	27	28	−10
Daiadhari	24 38		20	20	− 2
Kalianpur	24 7		18	18	...
Ladi	23 8		16	16	+ 2
Badgaon	20 44		13	13	+ 5
Damargida ...	18 3		10	10	+ 8
Cape Comorin ...	8 9		3	3	+15

10. In the following table the results of observation and calculation are compared :—

TABLE III.

Station.	Differential Deflections.		Discrepancy.
	By Observation. =O.	By Calculation. =C.	=C−O.
Dehra Dun ...	−38	−54	−16
Kaliana ...	− 7	−18	−11
Noh	0	−10	−10

Station.	Differential Deflections. By Observation. =O.	By Calculation. =C.	Discrepancy. =C−O.
Daiadhari ...	+ 1	− 2	− 3
Kalianpur ...	...	...	...
Ladi	− 5	+ 2	+ 7
Badgaon ...	− 8	+ 5	+13
Damargida ...	− 3	+ 8	+11
Cape Comorin ...	+ 2	+15	+13

11. At stations immediately north of Kalianpur the deflection by theory is northerly, but the observed deflection southerly; at stations immediately south the observed deflection is northerly and the theoretical deflection southerly. There appears therefore to be some hidden cause which is tending to reduce the northerly deflections at northern stations and to increase the northerly deflections at southern stations; and I have been led to infer the existence of an underground chain of excessive density that crosses Central India for 1,000 miles, and which underlies Balasore, Mandla, Bhopal, and Jodhpore. The attraction of this chain at stations situated to the north of it is opposed to Himalayan attraction; at stations situated to the south of it the two attractions act in concert. The chain imposes a wave on the curve of Himalayan attraction, and masks the true effects of the latter. If the hypothesis of the chain is correct, then the change in the sign of the deflections that occurs approximately along the parallel of 24° is not due in any way to the fact that this is the parallel of the station of reference. The proximity of the station of reference to the line of the chain appears, indeed, to be accidental. The significance that I attached to it in the early stages of this investigation appears to have been undeserved.

12. If a line exists towards which all plumb-lines from both sides throughout its entire length are deflected, the conclusion that it overlies a source of attraction may seem obvious, but it is not obvious. The hidden chain of Central India is so large that its presence has escaped detection. The idea that deflections of the plumb-line are accidental and due to "*local* attractions" is general, and every unexplained deflection is involuntarily attributed to a cause hidden *in the immediate* vicinity. When on flat plains we meet with a southerly deflection in latitude 27° and a northerly deflection in latitude 18°, we habitually prefer to assume two separate *local* hidden causes, rather than ascribe both deflections to a distant central cause.

13. The position of the underground chain coincides in places with the Vindhyan Mountains; but these latter are insufficient to produce the effects attributed to the chain; moreover, the effects of the chain continue to be observed to the east and to the west after the Vindhyas have ceased to be visible.

14. One feature of the chain is worthy of note: its course

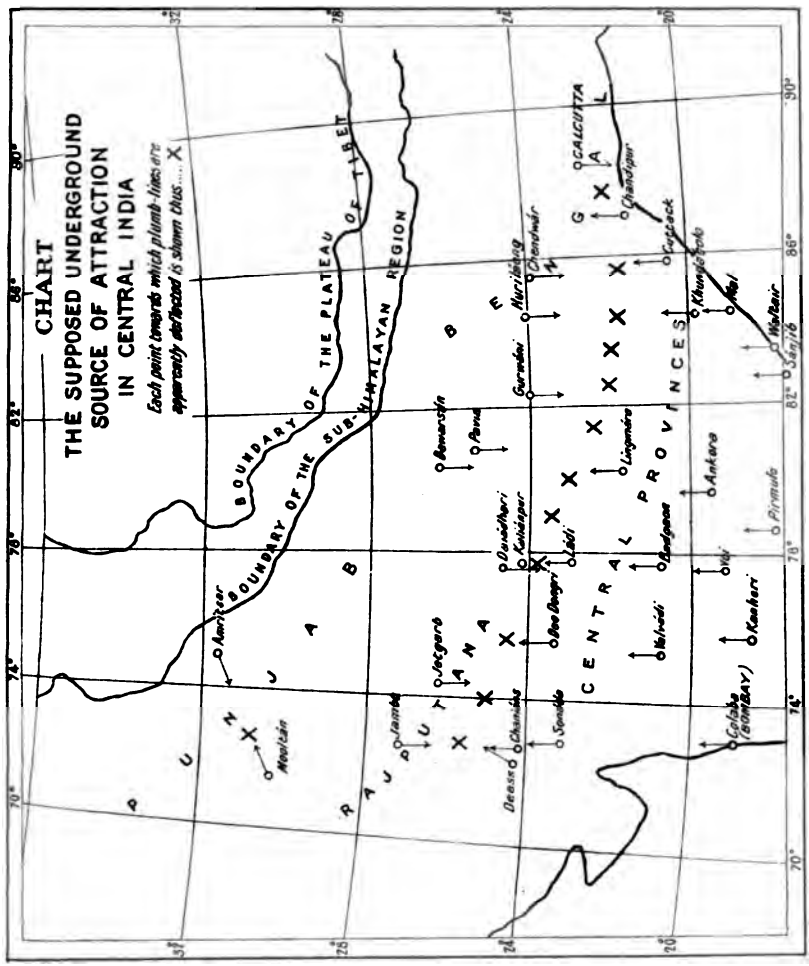


CHART
THE SUPPOSED UNDERGROUND SOURCE OF ATTRACTION IN CENTRAL INDIA
Each point towards which plumb-lines are apparently deflected is shown thus.... X
BOUNDARY OF THE PLATEAU OF TIBET
BOUNDARY OF THE SUB-HIMALAYAN REGION
CENTRAL PROVINCES
BENGAL
CALCUTTA
Amritsar
Mooltan
Jeypore
Deesa
Chanda
Sonepur
Benares
Pawa
Gurwahi
Hurriahug
Chendwar
Chandpur
Kolpack
Khungpack
Hoi
Wai Reir
Sajjia
Ankara
Pirmuli
Kanheri
Golaba (Bombay)
Lingoniro
Bodgaon
Nilwai
Seoni
Deodeori
Kaidapur
Jeri
Jee Dongri
82°
86°
90°
78°
74°
70°
32°
28°
24°
20°

UNIVERSITY

can be traced from longitude 88° to longitude 73°, and runs from E.S.E. to W.N.W., *in apparent parallelism with the Himalayas.* In the Punjab, to the *west* of the Himalaya Mountains, the longitude arc, Amritsar—Mooltan, reproduces the same extraordinary result as the latitude observations have given in Bengal to the *south* of the Himalayas. Just as the plumb-lines on all meridians from 88° to 73° seem to be deflected inwards towards one line, so are the plumb-lines at Amritsar and Mooltan deflected inwards towards the low-lying alluvium and away from the mountain masses. A chart is attached to illustrate the course of the chain (Plate 6).

15. It cannot be assumed that the discrepancies shown in Table III. are the actual effects of the chain. It is possible that the Himalayan mass is compensated to some extent by subjacent deficiencies of matter. The numerical discrepancies in Table III. have been derived without any such compensation being assumed.

16. In the following table are shown the discrepancies that occur between theory and observation if we assume the attraction of the Himalayas to be compensated to the extent of one-third, one-half, and two-thirds its normal force respectively. As Kalianpur is under the influence of the supposed chain, Cape Comorin has been now taken as the station of reference.

TABLE IV.

Station.	Discrepancies between theory and observation, the attraction of the Himalayan ranges and Tibetan plateau being assumed compensated to the extent of		
	⅓	½	⅔
Dehra Dun	− 6	+ 6	+17
Kaliana	−13	− 7	− 2
Noh	−15	−10	− 6
Daiadhari	−10	− 7	− 5
Kalianpur	− 8	− 5	− 3
Ladi	− 2	+ 1	+ 3
Badgaon	+ 3	+ 5	+ 7
Damargida	0	+ 2	+ 3
Cape Comorin	—	—	—

It will be seen that discrepancies of 13″ and 15″ continue to appear, if a theory of a one-third compensation be adopted. The theory of a two-thirds compensation renders the effects of the chain approximately equal and opposite, but introduces a discrepancy of 17″ at Dehra Dun.

17. In the following table are shown the discrepancies that occur between theory and observation if we assume the attraction of the successive Himalayan ranges to be uncompensated and that of the Tibetan plateau to be compensated to the extent of one-third, one-half, and two-thirds its normal force respectively :—

TABLE V.

Station.	Discrepancies between theory and observation, the attraction of the Tibetan plateau being assumed compensated to the extent of		
	½	⅔	¾
Dehra Dun	−12	− 4	+4
Kaliana	−14	− 9	−4
Noh	−15	−11	−8
Daiadhari	−10	− 8	−5
Kalianpur	− 8	− 6	−3
Ladi	− 2	+ 1	+3
Badgaon...	+ 4	+ 5	+7
Damargida	+ 1	+ 2	+3
Cape Comorin	—	—	—

The hypothesis that the attraction of the outer Himalayan ranges are uncompensated, and that that of the Tibetan plateau is compensated to the extent of two-thirds its normal force, removes gross discrepancies and renders the effects of the chain at equidistant stations to the north and south of it equal and opposite. It makes the crest of the chain cut the meridian of 77° 30′ in latitude 23° 30′, and it attributes to the chain a maximum effect of 8″ at 200 miles north and south of its crest.*

18. This attempt to disentangle the effects of the chain from those of the Himalayas, and to obtain a definite numerical idea, is put forward more as an illustration of the data than as an exact solution of the problem. The hypothesis that the effects of Himalayan attraction are probably entangled with those of a chain running parallel to the Himalayas at an average distance of 400 miles affords, however, an explanation of the large deflections at Dehra Dun, of the southerly deflections north of latitude 24°, and of the northerly deflections south of latitude 24°.

On Periodic Orbits. By E. T. Whittaker.

The object of this note is to establish the results numbered (I) and (II) below: they relate to the theory of periodic solutions of the differential equations of dynamics, a theory which the researches of Hill, Poincaré, and Darwin have shown to be of great importance in dynamical astronomy.

Consider the motion of a particle in a plane, under the action of conservative forces. Let x, y be its coordinates at time t, referred to any fixed rectangular axes; its mass may be taken

* The discrepancies at the seven central stations are assumed to be due to the chain.

to be unity without affecting the generality of the investigation. Let $f(x, y)$ be its potential energy when at the point (x, y), so that its total energy may be taken to be

$$\tfrac{1}{2}\left(\frac{dx}{dt}\right)^2 + \tfrac{1}{2}\left(\frac{dy}{dt}\right)^2 + f(x, y).$$

The differential equations of motion of the particle form a system of the fourth order, and their general solution consequently involves four arbitrary constants. One of these constants is, however, merely the constant additive to t, which determines the epoch in the orbit, and so there are only ∞^3 really distinct orbits. This triple infinity of orbits can be arranged in sets, each containing a double infinity of orbits, by associating together those orbits which correspond to the same value of the constant of energy. We shall consider one such set of ∞^2 orbits, characterised by the condition that the constant of energy has the value h, so that

$$\tfrac{1}{2}\left(\frac{dx}{dt}\right)^2 + \tfrac{1}{2}\left(\frac{dy}{dt}\right)^2 = h - f(x, y).$$

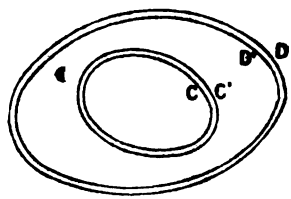
These orbits are defined analytically by means of the principle of least action; namely, that the orbit between two given points (x_0, y_0) and (x_1, y_1) is such as to make the value of the expression

$$\int \{h - f(x, y)\}^{\frac{1}{2}} \{(dx)^2 + (dy)^2\}^{\frac{1}{2}}$$

stationary as compared with other curves joining the given terminal points (x_0, y_0) and (x_1, y_1). Our attention will be directed particularly to those orbits which are *periodic*, i.e. which are in the form of closed curves.

1°. *A criterion which may be used in the discovery of periodic orbits.*

Consider any simple closed curve C in the plane of xy; and let another simple closed curve C' be drawn, enclosing C and



differing only slightly from it. We may regard C′ as defined by an equation of the form

$$\delta p = \phi(\gamma)$$

where δp is the normal distance between the curves C and C′, and γ is the inclination of this normal distance to the axis of x. Then if I be the value of the integral

$$\int \{h - f(x, y)\}^{\frac{1}{2}} \{(dx)^2 + (dy)^2\}^{\frac{1}{2}} \quad .$$

when the integration is taken round the curve C, and if $I + \delta I$ denote the value of the same integral when the integration is taken round the curve C′ (so that the symbol δ denotes an increment obtained in passing from C to C′), we have

$$\delta I = \int \{(dx)^2 + (dy)^2\}^{\frac{1}{2}} \delta \{h - f(x, y)\}^{\frac{1}{2}} + \int \{h - f(x, y)\}^{\frac{1}{2}} \delta \{(dx)^2 + (dy)^2\}$$

But

$$\delta \{h - f(x, y)\}^{\frac{1}{2}} = -\tfrac{1}{2} \{h - f(x, y)\}^{-\frac{1}{2}} \left(\frac{\partial f}{\partial x} \delta x + \frac{\partial f}{\partial y} \delta y \right)$$

$$= -\tfrac{1}{2} \{h - f(x, y)\}^{-\frac{1}{2}} \left(\frac{\partial f}{\partial x} \cos \gamma + \frac{\partial f}{\partial y} \sin \gamma \right) \delta p,$$

since $\delta x = \delta p \cos \gamma, \qquad \delta y = \delta p \sin \gamma.$

Also

$$\delta \{(dx)^2 + (dy)^2\}^{\frac{1}{2}} = \delta p \, . \, d\gamma$$

$$= \frac{\delta p}{\rho} \{(dx)^2 + (dy)^2\}^{\frac{1}{2}},$$

where ρ is the radius of curvature of the curve C at the point (x, y).

Thus

$$\delta I = \int \delta p \{(dx)^2 + (dy)^2\}^{\frac{1}{2}} \{h - f(x, y)\}^{-\frac{1}{2}} \left\{ \frac{h - f(x, y)}{\rho} - \tfrac{1}{2} \cos \gamma \frac{\partial f}{\partial x} - \tfrac{1}{2} \sin \gamma \frac{\partial f}{\partial y} \right\}.$$

This equation shows that if the quantity

$$\frac{h - f(x, y)}{\rho} - \tfrac{1}{2} \cos \gamma \frac{\partial f}{\partial x} - \tfrac{1}{2} \sin \gamma \frac{\partial f}{\partial y}$$

is positive at all points of C, then δI is positive, and so the quantity I has its value increased when any curve surrounding C and adjacent to C is taken instead of C as the path of integration.

Now suppose that another simple closed curve D can be drawn enclosing C, and such that at all points of D the quantity

$$\frac{h - f(x, y)}{\rho} - \tfrac{1}{2} \left(\cos \gamma \frac{\partial f}{\partial x} + \sin \gamma \frac{\partial f}{\partial y} \right)$$

is negative. Then, in the same way, it can be shown that the quantity I is increased when any simple closed curve D', enclosed by D and adjacent to D, is taken instead of D as the path of integration.

When, therefore, we consider the aggregate of all simple closed curves situated in the ring-shaped space bounded by C and D—which is assumed to contain no singularity of the function $f(x, y)$—it is clear that the curve which furnishes the greatest value of I cannot be C or D, and cannot coincide with C or D for any part of its length. There exists, therefore, among the simple closed curves of this aggregate one or more curves K for which the value of I is greater than for all the other curves of the aggregate. Since K does not coincide with C or D along any part of its length, it follows that the curves adjacent to K are all members of the aggregate in question, and hence that the curve K furnishes a stationary value of I as compared with all the curves adjacent to it. The curve K is therefore an orbit in the dynamical problem. We have thus arrived at the theorem

I. *If one closed curve be enclosed by another closed curve, and if the quantity*

$$\frac{h-f(x, y)}{\rho}-\tfrac{1}{2}\cos\gamma\frac{\partial f}{\partial x}-\tfrac{1}{2}\sin\gamma\frac{\partial f}{\partial y}$$

be positive at all points of the inner curve and negative at all points of the outer curve, then in the ring-shaped space between the two curves there exists a periodic orbit of the dynamical problem.

This result may be regarded as an analogue, in the theory of periodic orbits, of those theorems in the theory of equations which furnish the position of the roots by criteria depending on the sign of expressions connected with the equation. As the quantity

$$\frac{h-f(x, y)}{\rho}-\tfrac{1}{2}\cos\gamma\frac{\partial f}{\partial x}-\tfrac{1}{2}\sin\gamma\frac{\partial f}{\partial y}$$

can be immediately calculated for every point on the curves C and D, depending as it does only on the potential-energy function and the curves themselves, this result furnishes a means of detecting the presence of periodic orbits. Thus if we take, for example, the potential-energy function to be that due to two Newtonian centres of force of intensity 50 at the points (1, 0) and (− 1, 0), so that

$$f(x, y)=-\frac{50}{\{(x-1)^2+y^2\}^{\frac{1}{2}}}-\frac{50}{\{(x+1)^2+y^2\}^{\frac{1}{2}}},$$

and take $h=-\frac{1}{2}$, and choose the curves C and D to be circles whose centre is at the origin and whose radii are 80 and 120 respectively, it is easily found that the conditions mentioned above are satisfied, and that the existence of a periodic orbit in the ring-shaped space between these circles can be inferred.

2°. *An integral connected with periodic orbits.*

We shall now suppose that the field of force in the dynamical problem considered is due to several centres of force, attracting according to the Newtonian law of the inverse square of the distance. We shall consider a periodic orbit, enclosing any number of these centres of force, and shall establish the following theorem :

The integral

$$\frac{1}{2\pi}\iint\left[\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\log\{h-f(x,y)\}\right]dxdy,$$

where the integration is taken over the interior of any periodic orbit, is equal to the number of centres of force enclosed by the orbit, diminished by two.

Since the quantity $\{h-f(x, y)\}$ is infinite at each centre of force, it is necessary to discuss the legitimacy of integrating over a region which contains centres of force.

Suppose then that each centre of force is surrounded by a small circle having its centre at the centre of force. Let the periodic orbit be denoted by C, and let these small circles be denoted by $\gamma, \gamma', \gamma'', \ldots$. Then if S denote the region which is contained within C but exterior to $\gamma, \gamma', \gamma'', \ldots$ we have by the well-known theorem on the conversion of integrals taken over an area into integrals taken round the boundary of the area, that

$$\frac{1}{2\pi}\iint_S\left[\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\log\{h-f(x,y)\}\right]dxdy$$

$$=\frac{1}{2\pi}\left[\int_C-\int_\gamma-\int_{\gamma'}-\int_{\gamma''}-\ldots\right]$$

$$\left[\frac{\partial}{\partial x}\log\{h-f(x,y)\}\,dy-\frac{\partial}{\partial y}\log\{h-f(x,y)\}\,dx\right]$$

where the integration on the left-hand side is taken over the region S, and the integrations on the right-hand side are to be taken in the counter-clockwise direction round the curves C, $\gamma, \gamma', \gamma'', \ldots$ respectively.

Now the integral previously denoted by I, when taken between any two points of a periodic orbit, must have a value that is stationary as compared with the integral taken along any adjacent path joining the two points; the quantity previously denoted by δI must therefore be zero when the integral is taken along the arc of a periodic orbit between any two points of it; and consequently, since the quantity δp which occurs in the expression for δI is arbitrary, we must have the equation

$$\frac{h-f(x,y)}{\rho}-\tfrac{1}{2}\cos\gamma\frac{\partial f}{\partial x}-\tfrac{1}{2}\sin\gamma\frac{\partial f}{\partial y}=0$$

satisfied at every point of a periodic orbit; that is, we have the equation

$$\frac{2\{h-f(x,y)\}\{(dx)^2+(dy)^2\}^{\frac{1}{2}}}{\rho}=\frac{\partial f}{\partial x}dy-\frac{\partial f}{\partial y}dx$$

or

$$-2d\gamma=dy\frac{\partial}{\partial x}\log\{h-f(x,y)\}-dx\frac{\partial}{\partial y}\log\{h-f(x,y)\}$$

satisfied at every point of the curve C. We have therefore

$$\frac{1}{2\pi}\int_C\left[\frac{\partial}{\partial x}\log\{h-f(x,y)\}dy-\frac{\partial}{\partial y}\log\{h-f(x,y)\}dx\right]$$

$$=-\frac{1}{\pi}\int_C d\gamma=-\frac{2\pi}{\pi}$$

$$=-2.$$

We have next to consider the integrals which arise from the curves γ, γ', γ'' . . . We shall take first the integral arising from the curve γ, and, for simplicity, will suppose that the corresponding centre of force is at the origin, so that γ is a small circle with the origin as centre, and we can write

$$h-f(x,y)=\frac{\mu}{(x^2+y^2)^{\frac{1}{2}}}+\phi(x,y)$$

where μ is a constant and $\phi(x,y)$ is a function which is finite and continuous in the vicinity of the origin.

Then for points on γ we have, denoting the radius of γ by ρ,

$$\frac{\partial}{\partial x}\log\{h-f(x,y)\}=\frac{-\frac{\mu x}{\rho^3}+\phi_x(x,y)}{\frac{\mu}{\rho}+\phi(x,y)}$$

$$=-\frac{x}{\rho^2}+\text{terms which, when } \rho \text{ is small, are less important than this.}$$

Similarly

$$\frac{\partial}{\partial y}\log\{h-f(x,y)\}=-\frac{y}{\rho^2}+\text{less important terms.}$$

Thus

$$-\frac{1}{2\pi}\int_{\gamma}\left[\frac{\partial}{\partial x}\log\{h-f(x,y}\}\,.\,dy-\frac{\partial}{\partial y}\log\{h-f(x,y)\}\,dx\right]$$

$$=\frac{1}{2\pi\rho^2}\int_{\gamma}(xdy-ydx)+\text{terms which may be neglected in comparison with these}$$

$$=\frac{2\pi\rho^2}{2\pi\rho^2}$$

$$=1.$$

Similarly each of the integrals arising from $\gamma', \gamma'', \ldots$ has the value 1.

Thus we have

$$\frac{1}{2\pi}\iint_{S}\left[\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\log\{h-f(x,y)\}\right]dxdy$$

$$=-2+1+1+1+\ldots$$

the number of 1's on the right-hand side of the equation being equal to the number of centres of force enclosed by the periodic orbit C, and thus

$$\frac{1}{2\pi}\iint_{S}\left[\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\log\{h-f(x,y)\}\right]dxdy$$

$$=\text{the number of centres of force enclosed by the periodic orbit, diminished by two.}$$

Now it appears from this that the result is the same whatever be the radii of the small circles $\gamma, \gamma', \gamma'', \ldots$ provided they are infinitesimally small. Thus we are entitled to speak of the integral of the quantity

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\log\{h-f(x,y)\}$$

taken over the interior of the contour C, because the arbitrary element of choice in the circles $\gamma, \gamma', \gamma'', \ldots$ does not affect the value of the integral. We thus obtain the result—

II. *The integral*

$$\frac{1}{2\pi}\iint\left[\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\log\{h-f(x,y)\}\right]dxdy,$$

where the integration is taken over the interior of any periodic orbit, is equal to the number of centres of force enclosed by the orbit, diminished by two.

It may be observed that if the centres of force are not Newtonian, *i.e.* do not attract according to the law of the inverse square of the distance, the method which has been followed will lead to an analogous but slightly different result from that enunciated above.

Comparison of Photographic and Visual Magnitudes of the New Star in Perseus. By W. H. Robinson.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

Observations of the brightness, spectrum, colour, position, motion, and nebulous envelope of *Nova Persei* have from time to time been published, but very few photographic magnitudes of the star have as yet appeared. The results given in the present paper may therefore be of some interest and value.

Visual observations of the new star were commenced at the Radcliffe Observatory on February 25, when the writer—on his own initiative—commenced a series of thirty-three photographs of the region of the *Nova*.

The instrument employed was a half-plate camera with 1-inch doublet of superior quality covering a field of about 30° diameter. The camera was mounted on a small equatorial stand, and was readily adjustable to any desired position. The images of the stars were recorded as trails, no clock-work being introduced. Ilford Special Rapid plates were employed, and the development was effected with pyro-gallic.

The photographic magnitudes given in the present paper have been obtained in the following manner :—

A list of comparison stars, fourteen in number, was first prepared (Table I.), care being taken to select, where possible, only such stars as were in the immediate vicinity of the *Nova*, and evenly distributed around it ; but in order to include the five brightest stars in this list it was found necessary to take in an area greater than that for the nine fainter ones, which are all contained within a field 3° by 5°.

The group of moderately bright stars near *a Persei* is clearly shown on most of the plates, but its zenith-distance is much less than that of the new star, and is in consequence unsuitable for determining magnitudes by the differential method. The inclusion of the stars comprising this group would have necessitated the application of absorption-corrections, more or less doubtful in amount ; and since the density of the trails of stars of any given magnitude increases with their declinations, further slight corrections depending on this cause would have been necessary. For these reasons this group has not been used and has not been included in the list.

The stars selected for comparison of magnitudes with the *Nova* were the following :—

TABLE I.

List of Comparison Stars.

Star's Name.	Tabular Mag. (Harvard Scale.)	Star's Name.	Tabular Mag. (Harvard Scale.)
Capella ...	... 0·18	*l* Persei	4·84
α Persei ...	... 1·94	30 Persei	5·37
β Persei ...	... 2·31	36 Persei	5·40
ε Persei ...	... 3·04	Arg. Z. + 45°, 811	5·64
δ Persei ...	... 3·18	Arg. Z. + 43°, 818	5·97
ν Persei ...	... 3·90	Arg. Z. + 44°, 734	6·23
κ Persei ...	... 4·01	Arg. Z. + 42°, 795	6·30

The trails of the comparison stars and *Nova* were examined in transmitted light with a focussing glass, and their densities estimated by steps of sequences on an arbitrary scale of approximately ten or fifteen steps to a magnitude, the brightest star on the plate, *Capella*, being taken as very nearly zero, and *ν Persei* as 50.

The portions of the trails selected for comparison were, with very few exceptions, those corresponding to the same G.M.T.'s of exposures. The reliability of these estimations is strengthened by the fact that not until the final stage of conversion from densities into magnitude had been completed was any reference made to magnitudes of the *Nova* from other sources.

When a series of estimations had been obtained in this way the results were laid aside, and a second examination of the plates, on the same lines, was independently carried out. A duplicate series was thus secured, the results of which exhibited such close agreement with those of the first that further measurements were considered unnecessary.

The two series of results are shown in the following table, each result being the mean of several estimations.

TABLE II.

Mean Photographic Scale Estimations of Brightness of Comparison Stars.

Star's Name.	1st Series.	2nd Series.	Adopted Mean.
Capella	4	3	3·5
β Persei	21	21	21
α Persei	23	21	22
ε Persei	29	28	28·5
δ Persei	32	32	32
ν Persei	50	50	50
κ Persei	60	59	59·5
l Persei	63	63	63

Star's Name.	1st Series.	2nd Series.	Adopted Mean.
30 Persei	66	66	66
Arg. Z. +45°, 811	68	67·5	68
36 Persei	71	71	71
Arg. Z. +43°, 818	80	81	80·5
Arg. Z. +44°, 734	81	81·5	81
Arg. Z. +42°, 795	82	82·5	82

The magnitude-equivalents for the arbitrary scale were next determined.

On square-ruled paper the scaled and tabular values were plotted, the former, from Table II., as ordinates, and the latter, from Table I., as abscissæ; the points thus obtained and a smooth curve drawn through them are exhibited in fig. 1.

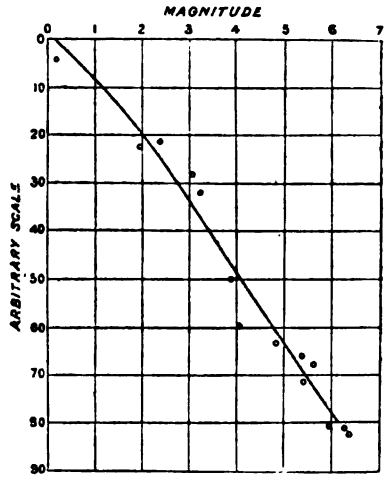


FIG. 1.—The position near 60 scale reading is that of κ Persei, an orange-coloured star.

From this curve the following equivalents were deduced :—

TABLE III.

Conversion of Scale into Magnitude.

Scale.	Magnitude Equivalent.	Scale.	Magnitude Equivalent.
0	0·15	30	2·75
5	0·65	35	3·10
10	1·15	40	3·45
15	1·60	45	3·75
20	2·00	50	4·05
25	2·40	55	4·40

Scale.	Magnitude Equivalent.	Scale.	Magnitude Equivalent.
60	4·75	75	5·80
65	5·10	80	6·15
70	5·45		

The equivalents given in Table III. were then adopted in forming the photographic magnitudes of the *Nova* shown in columns 5 and 6 of Table IV. A satisfactory agreement of the two sets of magnitudes is shown to exist. The greatest differences occur at the beginning of the series when the number of stars available for comparison was very limited and scattered over a comparatively large field, as before stated.

The second column of Table IV. contains the G.M.T. of exposure. The last column gives the visual magnitudes from Radcliffe observations, made at nearly the same G.M.T.'s, published in the *Monthly Notices* of the R.A.S., 1901 March, April, and May.

The general agreement of the last two columns—photographic and visual magnitudes of the *Nova*—is very striking. On two dates only, April 15 and 20, the differences of magnitude exceed 0·25, and in both these cases the photographic magnitude is *brighter* than the visual.

The eight bracketed results in column 7, independently derived from different photographs, are also remarkably accordant.

TABLE IV.

Comparison of Photographic and Visual Magnitudes of Nova Persei.

No.	G.M.T. 1901.	Photographic Scaled Densities. 1st Series.	Photographic Scaled Densities. 2nd Series.	Photographic Magnitudes. 1st Series.	Photographic Magnitudes. 2nd Series.	Photographic Magnitudes. Means.	Visual Magnitudes (Means).
1	Feb. 25 8h	9	8·5	1·05	1·00	1·02	0·90
2	26 10	13	8	1·42	0·95	1·18	1·17
3	28 7	16	17	1·68	1·76	1·72	1·58
4	9	18	16	1·84	1·68	1·76	
5	March 1 8	23	21	2·24	2·08	2·16	1·99
6	5 7	27	24	2·54	2·32	2·43	2·42
7	9 9	46	44·5	3·83	3·72	3·77	3·61
8	9½	45	45	3·75	3·75	3·75	
9	11 11	45·5	46	3·78	3·81	3·80	3·93
10	12 11	44	44·5	3·69	3·72	3·71	3·87
11	13 8	44	47	3·69	3·87	3·78	4·03
12	16 8	46	46	3·81	3·81	3·81	3·83
13	9	43·5	46·5	3·66	3·84	3·75	
14	20 9	44	45	3·69	3·75	3·72	3·74
15	10½	45	45	3·75	3·75	3·75	
16	21 9½	48	47·5	3·93	3·90	3·92	3·91
17	11	51	47·5	4·12	3·90	[4·01	

No.	G.M.T.		Photographic Scaled Densities. 1st Series.	2nd Series.	Photographic Magnitudes. 1st Series.	2nd Series.	Means.	Visual Magnitudes (Means).
	1901.							
18	March 22	8h	63·5	65	5·00	5·10	5·05	5·20
19	23	9	45	42·5	3·75	3·60	3·68	3·92
20	25	8	65	65·5	5·10	5·13	5·12	5·15
21		11	65	66	5·10	5·17	5·13	
22	26	9	49	48·5	3·99	3·96	3·98	4·12
23	27	8	45	47	3·75	3·87	3·81	3·98
24		11	47	46	3·87	3·81	3·84	
25	28	9	61·5	59	4·85	4·68	4·76	4·61
26	30	9½	49·5	48	4·02	3·93	3·98	4·14
27		10½	50	49	4·05	3·99	4·02	
28	April 10	9	68	69	5·31	5·38	5·34	5·33
29	13	9	55·5	53	4·43	4·26	4·35	4·49
30	15	11	68	68	5·31	5·31	5·31	5·82
31	17	9	59	58	4·68	4·61	4·64	4·62
32	19	9½	67	70	5·24	5·45	5·34	5·13
33	20	9	71	71·5	5·52	5·56	5·54	5·83

No. 2. Not in good focus. Nos. 9 and 10. Very faint; very misty sky. No. 11. Images not good, too near edge of plate. No. 19. Varying images; cloudy. No. 30. Small altitude; trails good. No. 32. Very faint.

The last two columns of Table IV. are represented graphically in fig. 2. The ordinates of the two curves are, for the sake of clearness, separated by a constant quantity (one magnitude); unless this had been done the curves would have been superposed in places and would have presented a confused appearance.

A glance at this diagram will show that every change of

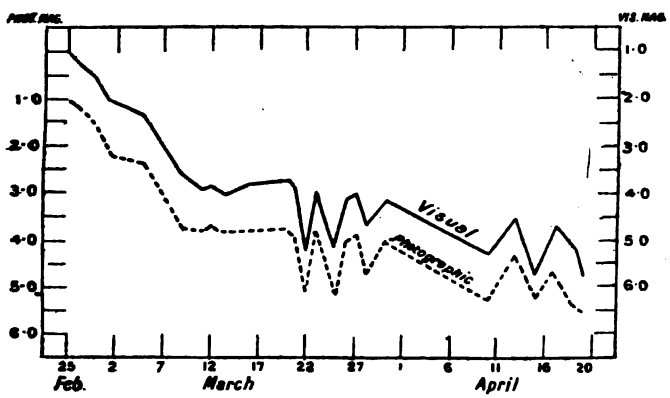


FIG. 2.—Comparison of Photographic with visual magnitude of Nova Persei.

brightness as determined visually has its counterpart in the photographic curve, so that the two corroborate each other in every particular.

The parallelism or identity of the curves in this figure appear the more remarkable when it is remembered that the *spectrum* of the star also exhibited considerable fluctuations in unison with those of magnitude, as proved by the extensive series of spectroscopic observations at Kensington and Stonyhurst. The director of the latter observatory, in a paper recently communicated to the *Astronomische Nachrichten* (No. 3756), says:—

"A comparison of all the photographic plates of the star's spectrum obtained at Stonyhurst with the light-changes observed at the Radcliffe Observatory, Oxford, has shown that the changes of the spectrum follow, not the phases of the light-curve, but the absolute magnitudes of the star's brightness. The new spectrum, which at first appeared to be associated with the minimum phase, was found on all the dates on which the star's magnitude was less than 4·57 both in March and April; and the old spectrum always returned when the magnitude was greater than 4·57."

Sir Norman Lockyer (*Proc. R.S.*, vol. lxviii. 231) writes:—

"Accompanying the great diminution in the light of the *Nova* observed on the evening of the 25th [March], the spectrum was found to have undergone a great change: the continuous spectrum had practically disappeared, and a line near D (probably helium, D_3) became more distinct. The other lines were hardly visible." The same astronomer further remarks:—"It has been noted that the lines 447, 501, and D_3 appear to vary with the magnitude of the star, becoming relatively more prominent towards a minimum" (*Proc. R.S.*, vol. lxviii. 403).

Closely related to the question of changes in the spectrum of the *Nova* is that of variation in the *visual colour*. On this subject Dr. Rambaut, in the *Monthly Notices* for 1901 April, wrote: "A comparison of the notes on the colour of the star with the variation in its brightness seems to indicate some relation between these two phenomena, and suggests that a diminution of light is accompanied by an increase in the redness of the star." In the next number of the *Notices* the Radcliffe Observer remarks:—"The suggestion made in the last paper that the change in tint was closely related to fluctuations in brightness has been fully confirmed." More recently Herr Osthoff has published (*Astronomische Nachrichten*, 3751) a diagram exhibiting the marked relationship which existed between the variations of visual magnitude and those of colour.

It would therefore appear that, notwithstanding the striking changes in the quality of the star's light, as shown by the spectroscope, and the changes observed in its colour, the variation in the general intensity of the light proceeded *pari passu*, whether measured visually or photographically.

The difficulty of obtaining magnitudes of the *Nova* from long-exposure photographs for comparison with visual magnitudes is

brought out clearly by Mr. H. Ellis in his paper entitled "Notes on some Photographs of *Nova Persei*," published in the *Journal of the British Astronomical Association*, vol. xi. No. 6. Mr. Ellis took his pictures of the *Nova* with a 5-inch portrait lens and with a large mirror on several nights from February 25 to March 10, using Ilford Special Rapid plates (carefully backed). He remarks:—"In examining these plates, it is very noticeable that the image of the *Nova* is large; in fact, it does not seem to have diminished in size, although by March 10 its light had much diminished and become very orange, with flashes of crimson, when viewed in the guiding telescope."

It will be seen in Table IV. of the present paper that a fall of nearly three magnitudes occurred between February 25 and about March 10.

Mr. Ellis proceeds: "In all the plates the image is larger than *a Persei*. . . . The reason of this, I think, must be the large gaseous envelope which the spectroscope shows to be present."

The nebulous envelope, if it existed at the time of Mr. Ellis' photographs, was not sufficiently actinic to be photographed with short exposures or by the trail method. The exposures by the trail method (within small limits of declination) possess the exceptional merit of being not only *short* but *always equal*; and these conditions seem to be essential when photographs of an object such as the *Nova* are required for comparison from night to night.

The chemically active quality of the light of the new star is emphasised by contrast with that of other reddish stars. This is shown on plate No. 7 (March 9, 9^h), which, after being exposed on the Nova, was exposed on the first magnitude orange-red star *a Orionis*, when it was at the same altitude as the new star and probably not so red.* From a discussion of the data afforded by this plate the resulting magnitudes were found to be:

	Photographic.	Visual.
a Orionis	3·20	0·91†
Nova Persei	3·77	3·61

It may be mentioned, in conclusion, that the trails were examined for any evidence of rapid changes of light similar to those seen on February 24 by Herr Archenhold,‡ but no sudden changes were found, except such as were attributable to atmospheric causes.

Radcliffe Observatory, Oxford: 1902 January 6.

* *Nova röthlich.* Harkányi (*A.N.* 3706). *Nova tief roth.* Köhl (*A.N.* 3709).

† Harvard Photometry.

‡ "Die plötzliche Lichtabnahme der Nova und ihr völliges Verschwinden waren so etwas Aussergewöhnliches, dass ich zunächst an eine atmosphärische Ursache dachte. Nur der Umstand, dass ich die umliegenden schwachen Sterne wie ν, ψ, δ, und σ Persei während dieser Zeit deutlich wahrnahm, liessen auch die Möglichkeit zu, dass es eine wirkliche Lichtabnahme der Nova sei" (*Ast. Nach.* No. 3694).

Period and Light Curve of 6685 *Y Lyræ.**

By A. Stanley Williams.

The earlier observations of this star seemed to suggest a moderately long period, and one of about eighty-six days was proposed by Dr. Hartwig in 1900,† whilst at about the same time I thought it might be forty-two days, or about half the above value. Observations of the star were commenced here in 1901 May with the object of solving this question, and after these had proceeded for some time it became evident that the real period was actually a very short one. The question was finally decided on August 18, on which date the star was observed shortly before the rise from minimum had commenced, and followed up to and past maximum; whilst further observations soon showed that the true period was very nearly half a day. About the same time Dr. Hartwig was making a series of observations of the star at the Bamberg Observatory. His earlier observations are referred to in *A.N.* 3744.‡ These were inconclusive, but further observations in the latter part of August made him suspect that the variable had a short period. Dr. Hartwig was unable to continue his observations at this time, but later on he was able to fully confirm the rapid variability of the star, and his observations are in good agreement with the others.

The results contained in the present paper are based upon a total of 239 visual observations. Fourteen of these were made by Dr. Hartwig with the 10-inch Bamberg refractor. The others were made at Hove with a 6¼-inch reflector, a power of 110 being usually employed, but occasionally one of 225 was made use of on moonlight or hazy nights. These observations are all included in the period comprised between 1901 May 13 and November 3. The following is a short description of the method of observation, the reduction of the observations, and the determination of the magnitudes of the comparison stars.

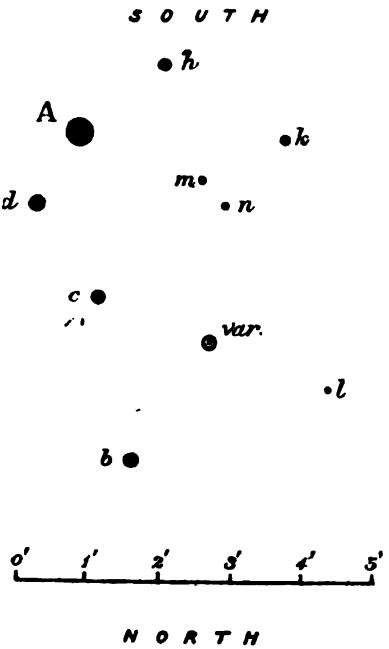
In order to eliminate the effects of what has been called "position error," three principal methods may be employed, namely (1) we may observe the group of stars under all possible angles of position with respect to a line through the eyes; (2) we may observe the group with the eyes always in the same position; and (3) in comparing each comparison star separately

* The star is designated *X Lyræ* in the "Companion to the Observatory." Its place for 1900 is α 18^h 34^m 12^s, δ +43° 51′·8.

† *Vierteljahrsschrift d. Astr. Gesell.*, Jahrg. 35, Heft 4, p. 276.

‡ In this note doubt is thrown upon the identity of the variable with a star of about 12^m, but they are actually one and the same object. It will appear from the present investigation that the light curve is rather a peculiar one, and that the star is only at all bright for about three hours out of twelve, whilst the period is so nearly half a day that it is possible to observe the star night after night for a long interval of time without any decided change of brightness becoming apparent.

with the variable we may always observe with the eyes parallel to, or in some fixed position with respect to, a line joining the two stars observed. The first of these methods will undoubtedly give the best results, since with it the effects of position error must be altogether eliminated. Its only drawback is that the time and labour required are both much increased—a serious matter, especially in the case of a faint and rapidly varying star.* Method (2) was made use of in the present series of observations.† The group was always observed so that a line through the stars A and *b* (see diagram below) was normal to a line through the eyes, *b* being above. By this method the effects due to position error are not eliminated, so far as regards the absolute magnitude of the star observed, but the observations will be strictly comparable *inter se*.‡



* In connection with this method and the question of position error generally reference should be made to the valuable papers by Dr. A. W. Roberts in the *Monthly Notices*, vol. lvii. p. 483, and vol. lix. p. 524.

† These remarks relate only to the Hove observations except where otherwise mentioned. Method (3) seems preferable on the whole to method (2), and is the one at present made use of by the writer. The reflector with rotating tube is very convenient for either method.

‡ The effect of a complete reversal of position is to produce a change of about half a magnitude in the relative brightness of two stars observed in a direction normal to a line through the eyes by the writer.

The comparison stars used are shown in the preceding diagram.* The observations were made by the method of Argelander, and the step values of the different comparison stars, as derived from the very numerous comparisons between the latter and the variable, are as under :—

Comp. Star.	Step Value.	Adopted Mag.
c	0·0	10·70
h	5·5	11·09
k	13·0	11·63
m	14·8	11·75
n	18·1	11·99
l	19·7	12·10

The magnitude of the star *c* was assumed to be 10·7, chiefly from its visibility in a $2\frac{3}{4}$-inch refractor. On a clear night it is just distinctly and *steadily* visible, with a power of 75 on this instrument. The $6\frac{1}{2}$-inch reflector has been considered to show distinctly and steadily stars down to $12^{m}\cdot5$ on clear nights with a power of 110. The comparison star *l* is near, though decidedly above, this limit, and its magnitude has been assumed to be 12·1. Assuming the foregoing values for *c* and *l*, the magnitudes of the other comparison stars, as determined from the step values, are given in the last column of the above table, the value of a step being $0^{m}\cdot071$. With reference to the comparison stars, it may be mentioned that *c*, *h*, and *l* have always appeared steady in brightness, and the comparisons made with them were usually satisfactory and consistent, particularly those with *l*. The other three stars *k*, *m*, and *n* have proved more unsteady, so that the comparisons with them were seldom quite satisfactory: *k* in particular has fluctuated so much as to give rise to the suspicion that it may be variable.

A somewhat elaborate system of weighting has been used in reducing the observations. The method of Argelander is capable of yielding most accurate results so long as the difference in brightness of the two stars compared does not exceed a few steps; but in proportion as such difference exceeds, say, 3 or 4 steps the result becomes less and less reliable. The following weights were finally adopted :—

	Weight
Comparisons with *l* not exceeding 3 steps	3
Comparisons with *l* above 3, but not exceeding 7 steps	2
Comparisons with other stars not exceeding 3 steps ...	2
Comparisons with *l* exceeding 7 steps	1
Comparisons with other stars exceeding 3 steps ...	1

* The positions of *h*, *k*, *m*, and *n* are only roughly estimated, but will be near enough to identify the stars. The bright star A is B.D. + 43°·3029 (8·1 mag.).

The comparisons with *l* were given increased weight because this star proved more satisfactory than any of the others. All the observations were reduced with the above weights, excepting that in a few cases less weights were assigned when the notes made at the time of observation seemed to show that this was necessary.

From a preliminary determination from 5 maxima observed between 1901 August 19 and October 20 the period of variation was found to be approximately $12^h\ 3^m\ 40^s{\cdot}6$. For the final determination of this element, however, photographic observations have been used, chiefly on account of the much greater length of time available. Two photographs, dated 1899 December 31 and 1900 September 3, show the variable exactly of the same relative brightness with respect to *c*, in both the two stars appearing as a double star with slightly unequal components.* These photographs were taken with a 4·4-inch portrait lens of about 20 inches equivalent focus, and a third one obtained with the same instrument on 1901 November 5 also shows the variable of the same brightness with respect to *c*. In the case of photographs of a rapidly varying star there is necessarily some uncertainty as regards the exact time corresponding to the image of the star on the plate. As the exposures are not very dissimilar,† it has been assumed in the present instance that this time corresponds to the middle of the exposures. As we are now only concerned with the period of variation, and not with the time of maximum, it is immaterial whether this assumption is correct or not, provided that this time corresponds to the same phase in all the photographs. Below are given the date and heliocentric Greenwich mean time of the exposures and the duration of the latter. The fifth column contains the interval in time by which the observations follow the adopted epoch of T_o ‡, and the last column the difference from the mean.

Plate.	Date.	Time.	Exposure.	Interval from T_o.	Diff. from Mean.
		h m	m	h m	m
46	1899 Dec. 31	6 40·4	63	0 54·2	−0·6
63	1900 Sept. 3	14 19·3	45	0 56·7	+1·9
149	1901 Nov. 5	9 9·4	32	0 53·6	−1·2

From these three observations the period of variation is :—

$$0^d{\cdot}5026876 = 12^h\ 3^m\ 52^s{\cdot}21$$

The remarkably close accordance of the three observations is no

* The photographic brightness of the variable is the same as the visual.

† Plate 46 was exposed longer than the others, but the night was slightly hazy, particularly towards the end, and this would tend to equalise matters.

‡ The time T_o, as explained further on, is the time when the variable attains to equality with the comparison star *l* in its rapid rise from minimum to maximum.

doubt to some extent an accident, but the star varies so rapidly near the time of maximum that I cannot think that any one of them can be in error by as much as 10^m, and the above period cannot be far wrong owing to the considerable interval of time covered by the observations, 1,341 periods being included between the first and last. It also satisfies all the visual observations.

Since the rise from minimum to maximum occurs with great rapidity, the instant when the variable attains to equality with the comparison star *l* has been adopted as the principal epoch. This instant is designated by T_0. There are twelve nights on which the variable was observed from minimum to maximum, and on eleven of these the maxima were also completely observed. The observations of each of these twelve nights were plotted separately upon squared paper, and a light curve drawn. From these light curves the times of T_0, and also the times of maximum, were determined by measurement. No mean light curve was made use of in this part of the work, but the results for each night were derived separately from the observations of that night. The reason for this was, chiefly, that some of the maxima seem to have been less acute than others, and I am not satisfied that this is all due to errors of observation. But though the maxima differ slightly in this way, the rise from minimum to near maximum is in every case represented by a straight line, so that the time T_0 can be very exactly determined. Table I., below, contains the dates and heliocentric Greenwich mean times of T_0. The mean of these times, corresponding to 1901 September 4, $12^h\ 20^m$, has been adopted as the principal epoch.

TABLE I.

Observed Times of T_0.

No.	Date. 1901.	Observed Time. h m	Computed Time. h m	O−C. m
1	Aug. 18	10 24·4	10 8·7	+15·7
2	19	10 12·3	10 16·5	− 4·2
3	20	10 12·3	10 24·2	−11·9
4	21	10 32·3	10 31·9	+ 0·4
5	22	10 42·2	10 39·7	+ 2·5
6	23	10 43·2	10 47·4	− 4·2
7	24	10 52·2	10 55·2	− 3·0
8	26	11 13·1	11 10·6	+ 2·5
9	Sept. 4	12 5·3	12 20·3	−15·0
10	Oct. 20	6 10·3	6 12·5	− 2·2
11	25	7 1·0	6 51·2	+ 9·8
12	Nov. 3	8 10·5	8 0·9	+ 9·6

The greater accordance of observations 4, 5, 6, 7, and 8 is probably due to the observer having acquired a settled manner

of observing and to the favourable weather prevailing at that time. No. 11 is from observations by Dr. Hartwig, and the residual here includes any error in the reduction of his observations to the scale of the others. With regard to this point there is a little uncertainty, since the Bamberg observations, made with a refractor, seem to make the star a little brighter than those made with the reflector.*

Table II., below, contains the observed times of maximum, with the intervals by which these follow the observed times of T_o.

TABLE II.

Observed Maxima.†

Date.	Greenwich M.T. h m	Interval from T_o. h m
1901 Aug. 18	11 51	1 29
19	11 32	1 22
20	11 34	1 24
21	11 33	1 3
22	11 33	0 53
23	11 45	1 4
24	12 13	1 23
26	12 11	1 0
Sept. 4	13 32	1 25
Oct. 20	7 10	0 59
Nov. 3	9 12	1 0

The mean of the times in the last column is 71^m, but from the mean light curve the interval is 60^m. The latter has been adopted as the true interval. The separate results vary from 53^m to 89^m, a difference which seems too great to be ascribed wholly to errors of observation.

The reduced observations of magnitude, having been arranged in order of distance from the time T_o, were formed into groups.

* Dr. Hartwig's observations are given below. The last column contains the magnitude according to the adopted scale.

	Greenwich M.T. h m	m		Mag.
1901 Oct. 25	7 1	*c* 0·74 Y		12·08
	7 12	*c* 0·7 Y		12·03
	7 23	*c* 0·4 Y	$0^m·35$ *l*	11·46
	7 33	*c* 0·25 Y	$0^m·5$ *l*	11·17
	7 41	*c* 0·15 Y		10·98
	7 57	*c* 0·15 Y	$0^m·6$ *l*	10·98

The night was not favourable, and cloud stopped observation after $7^h\ 57^m$. The rapid rise from near minimum to maximum is, however, very well shown, and, as in my observations, is represented by a straight line.

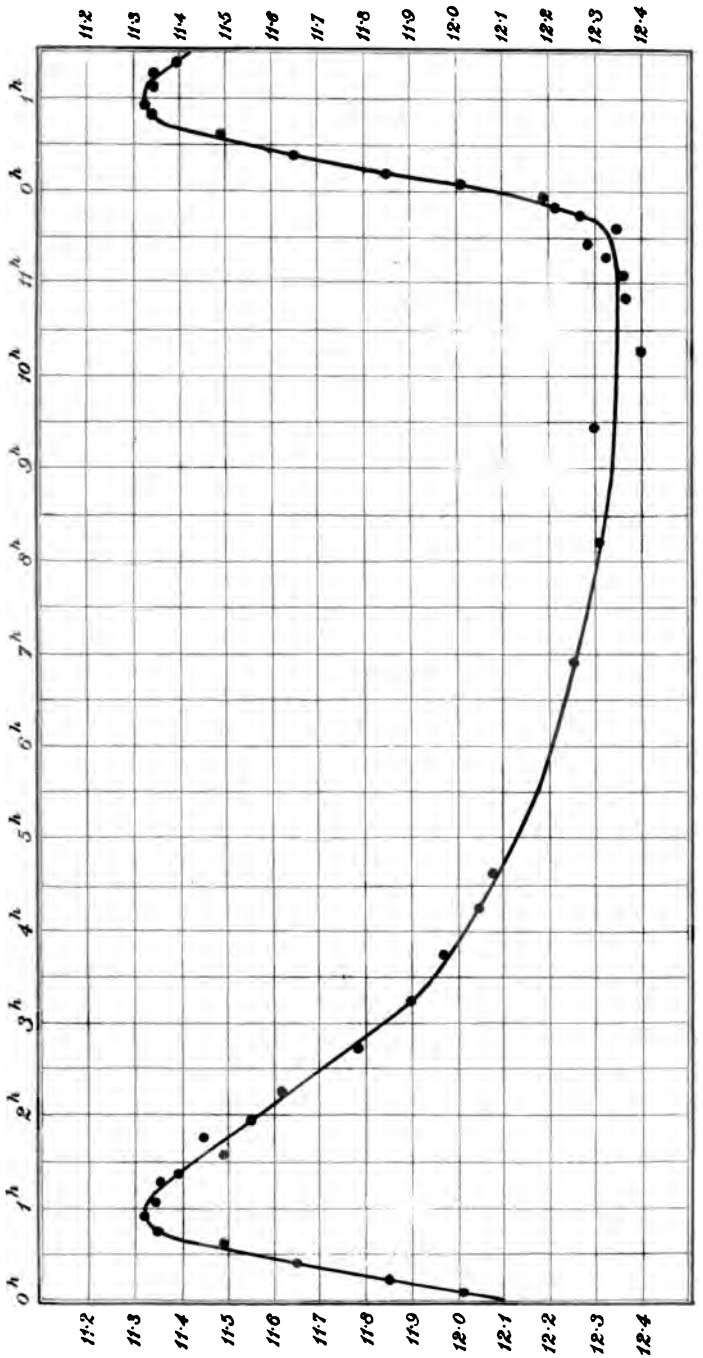
† Not reduced to the Sun.

For one hour before and two hours after T_0 the observations have been collected into 10-minute groups. The interval of 14^m preceding this epoch was divided into two equal groups. For the remaining portion of the period the observations have been formed into half-hourly groups, excepting between 5^h and 10^h after T_0, where they are not numerous enough to permit of this. Table III. contains the results of this grouping.

TABLE III.

Grouped Observations.

No.	Interval from T_0. h m	Observed Magnitude.	Magnitude from Curve.	O−C. m	Weight.	No. of Obs.
1	0 4	12·01	12·01	0·00	37	12
2	0 13	11·85	11·85	·00	48	10
3	0 25	11·65	11·65	·00	54	13
4	0 35	11·49	11·48	+ ·01	37	11
5	0 45	11·35	11·35	·00	43	11
6	0 53	1·33	11·33	·00	38	9
7	1 5	11·35	11·33	+ ·02	38	9
8	1 17	11·35	11·36	− ·01	14	4
9	1 24	11·39	11·39	·00	32	8
10	1 34	11·49	11·44	+ ·05	19	4
11	1 44	11·44	11·48	− ·04	33	9
12	1 56	11·54	11·54	·00	17	5
13	2 14	11·62	11·63	− ·01	60	15
14	2 43	11·78	11·77	+ ·01	55	12
15	3 15	11·90	11·90	·00	59	13
16	3 42	11·96	11·97	− ·01	30	8
17	4 16	12·04	12·04	·00	49	10
18	4 42	12·08	12·09	− ·01	11	3
19	6 54	12·26	12·26	·00	6	2
20	8 18	12·31	12·32	− ·01	27	9
21	9 27	12·30	12·34	− ·04	15	5
22	10 13	12·40	12·35	+ ·05	16	7
23	10 47	12·37	12·35	+ ·02	18	8
24	11 4	12·36	12·34	+ ·02	16	7
25	11 16	12·33	12·33	·00	16	5
26	11 25	12·28	12·33	− ·05	14	5
27	11 36	12·35	12·32	+ ·03	13	6
28	11 47	12·27	12·27	·00	21	7
29	11 53	12·22	12·22	·00	17	6
30	11 59	12·19	12·17	+ ·02	18	6



Light Curve of Y Lyræ.

In the above table col. 1 contains the number of the group; col. 2, the interval from T_0; col. 3, the observed magnitude, this being the weighted mean of the observations forming the group; col. 4, the mean magnitude, measured from the mean light curve; col. 5, the residual, observed − curve; col. 6, the weight, this being merely the sum of the weights of the separate observations; and col. 7, the number of observations to the group.* The 30 observed magnitudes having been plotted upon a large scale diagram, the mean light curve was carefully drawn, and the magnitudes in the 4th col. were measured from this. This light curve, on a smaller scale, is reproduced in Plate 7. The observations are in very satisfactory accordance, the average deviation of a group from the mean light curve being only 0·014 mag., whilst no residual exceeds 0·05 mag. It should be mentioned, moreover, that the observations forming a group are also generally very accordant, and that no observation has been rejected for discordance. The only observations not used consist of a few in which the variable was not seen, and was accordingly noted only as being fainter than a certain magnitude.

It will be seen that the mean light curve presents some rather peculiar features. The rise from minimum to maximum is very rapid; whilst immediately after the latter is attained the decline sets in, and the fall, though not so rapid as the rise, is yet very quick for the first two hours after maximum. One result of this is that the variable is only at all bright for about three hours out of the twelve, and for the remaining nine hours it is more or less faint. The light curve has thus a very close resemblance to that of what has been termed the "cluster type" of variable. This type has been recently described very fully in an interesting article by Professor S. I. Bailey,† in which the approximate light curves from photographic observations of eight of the variables in the cluster Messier 5 are reproduced. Reference should also be made here to a paper by Professor E. E. Barnard‡ on visual observations of some of the variables in the same cluster, and to one by Professor E. C. Pickering§ on the rate of increase of the light of three variable stars in the cluster Messier 3. In length of period also the present variable star bears a close resemblance to those of the cluster type, the average period of forty variables in Messier 5 being $12^h\ 37^m{\cdot}4$ according to Bailey, whilst the periods of the three in Messier 3 investigated by Pickering are stated to be $12^h\ 12^m\ 25^s$, $12^h\ 0^m\ 15^s$, and $12^h\ 24^m\ 31^s$.

Although the presence of so many variables of the type in star clusters would seem to show that such a condition is

* Each of these separate observations is itself generally based on comparisons with from two to four comparison stars.

† *Astrophysical Journal*, vol. x. pp. 255–260.

‡ *A.N.* 3519.

§ *Astrophysical Journal*, vol. xii. p. 159. See also a valuable paper by the same writer on variable stars in clusters in *A.N.* 3525.

peculiarly liable to give rise to this kind of variation, yet the existence of isolated stars, like *Y Lyræ*, belonging to the same class would indicate that it is not an essential condition. In other words the type is not peculiar to clusters.

Elements of Y Lyræ.

Period of variation	$0^d \cdot 5026876 = 12^h\ 3^m\ 52^s \cdot 21$.
Epoch of T_o	1901 Sept. 4, $12^h\ 20^m$ G.M.T. (J.D. 2415632·5138.)
Epoch of maximum	1901 Sept. 4, $13^h\ 20^m$ G.M.T. (J.D. 2415632·5554.)
Maximum brightness ...	$11^m \cdot 32$.
Minimum „ ...	$12^m \cdot 35$.*
Minimum to maximum ...	$1^h\ 40^m$.†
Maximum to minimum ...	$10^h\ 24^m$.
Ratio increase to decrease ...	0·16.

Computed Times of T_o.‡

1902.	G.M.T. h m	1902.	G.M.T. h m
April 1	3 6	Aug. 9	19 52
11	4 23	19	21 10
21	5 41	29	22 27
May 1	6 58	Sept. 8	23 44
11	8 16	18	0 54
21	9 33	28	2 11
31	10 50	Oct. 8	3 29
June 10	12 8	18	4 46
20	13 25	28	6 4
30	14 43	Nov. 7	7 21
July 10	16 0	17	8 38
20	17 17	27	9 56
30	18 35		

Hour: 1902 *January* 4.

* According to Dr. Hartwig, the actual range of variation is somewhat less than a magnitude.

† It has been assumed that the minimum occurs just before the rise commences, but the star actually remains practically stationary for two or three hours before the commencement of the rise.

‡ The maxima will follow these times by one hour.

Σ 1639. 68 *Comæ Berenicis.* By Thomas Lewis.

R.A.	$12^h\ 19^m\ 25^s$	1900	Mag. A 6·7
N.P.D.	63° 52′		Mag. B 7·9

The measures commence in 1827 by W. Struve; but they are few in number owing to the closeness of the components since 1880. It is undoubtedly binary, and as the distance is now increasing again it will become a fairly easy object and is worth attention.

Of course the orbit here given is only approximate, and is intended merely to call attention to the pair.

The annual means of the measures are :—

Year.	Angle.	Distance.	
	°	″	
1827·28	291·2	1·27	Σ (1)
29·39	289·7	1·15	Σ (3)
36·49	292·8	1·18	Σ
41·39	289·7	1·03	OΣ (1)
42·37	285·5	1·19	OΣ (2)
43·33	293·7	0·98	Maed. (1)
44·32	289·2	1·18	OΣ (1) Maed. (1)
48·35	288·8	0·96	Maed. (1)
55·32	282·2	0·97	OΣ (1)
56·48	288·1	0·87	Secchi (1)
57·33	283·6	0·84	Secchi (1)
58·34	283·0	1·00	De (4)
63·16	285·7	0·67	De (4)
70·31	275·8	0·74	OΣ (1)
75·25	273·6	0·40	De (1) Schiap. (4)
76·46	272·6	0·39	De (1)
77·41	271·4	0·40	De (1) Schiap. (4)
78·31	268·3	0·36	De (1)
79·31	268·7	0·4	Schiap. (2)
81·37	260·7	0·4	Schiap. (2)
82·39	258·1	0·39	Schiap. (4)
83·30	259·5	0·34	Engel (16) Schiap. (3)
84·37	243·7	0·38	Schiap. (2)
85·41	249·0 (?)	...	Schiap. (2)
87·39	236·0	0·22	Schiap.
89·40	215·6	0·2	H. Struve (1)
90·46	Single		H. Struve

Year.	Angle.	Distance.	
	°	"	
92·36	Single		Burnham (36-inch)
93	Single		Lewis (13-inch)
95	Single		Lewis (28-inch)
95·24	97·1	0·28	Lewis (1)
95·32	25·4	0·2	H. Struve (3)
96·34	19·3	0·15	Lewis (1)
97·26	12·7	0·25	Aitken (3) Lewis (2)
98·30	9·7	0·27	Aitken (3) Lewis (1)
99·37	3·0	0·26	Aitken (3) Lewis (3)
00·32	356·9	0·19	Bowyer (3) Lewis (3)
01·28	356·7	0·32	Aitken (3) Lewis (3) Bryant (1)

If from these measures we adopt the following six positions by taking means of neighbouring years—

	°	"
1831·05	291·2	1·20
43·94	289·4	1·07
58·21	284·5	0·87
76·21	271·6	0·45
82·35	259·4	0·38
85·88	239·9	0·30

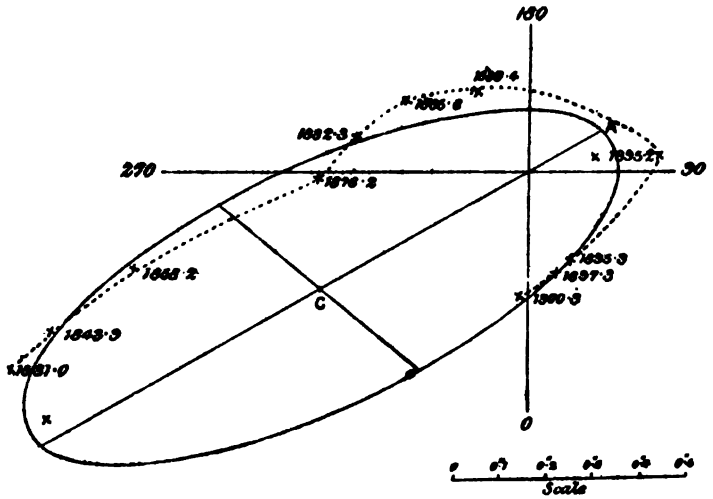
and plot them out, we find that so far as direction alone is concerned they are very closely represented by a straight line in the direction 123°·0; but the rate of motion along this line is

from 1831 to 1843	·092	in one year
1858	·126	„
1876	·171	„
1882	·173	„
1885	·186	„
1889	·210	„

which clearly indicates orbital motion, and explains why the pair was not measurable in 1892 and 1893. It also shows that the recent measures are in the first quadrant.

We then have in addition to the above six normal places—

1895·24	97·1	0·28
1897·30	13·1	0·22
1900·32	358·9	0·26



These positions are shown in the figure which is the adopted apparent ellipse, from which the following elements for the true ellipse have been computed :—

$\tau = 1892{\cdot}0$	$\Omega = 109° 12'$
$\mu = 180$ years	$\lambda \quad 18 \quad 7$
$\epsilon = 0{\cdot}70$	$\gamma \quad 58 \quad 9$
$a = 0''{\cdot}71$	$\phi \quad 42°{\cdot}88$

The measures of H. Struve were received after this paper was written. They uphold the binarity and conclusions here given in the most decided manner.

1901 *December* 28.

Observations of the Satellite of Neptune from Photographs taken at the Royal Observatory, Greenwich, in 1899–1900.

(*Communicated by the Astronomer Royal.*)

By inadvertence the publication of these results for the opposition of 1899–1900 has been delayed till now.

The photographs were taken with the 26-inch refractor of the Thompson equatorial. An occulting shutter immediately in front of the plate has been used to screen the planet during the greater part of the long exposure on the satellite, a series of very short exposures (usually twenty of one second each) being given to

Neptune at regular intervals (usually each minute) by lifting the occulting arm. The orientation was determined usually by means of a pair of short-exposure images of *Neptune*, the clock being put out of gear for seven seconds between the exposures to give a convenient displacement in R.A. The photographs were measured in reversed positions of the plate by each of two observers. The mean values of position angle and distance as measured are given in the following table, the tabular positions being computed from the data given in the *Connaissance des Temps*, based on Mr. H. Struve's elements, the eccentricity of the orbit being neglected owing to the uncertainty as to the present position of the periastron.

Positions of Neptune's Satellite measured on Photographs taken with the 26-inch Refractor.

Date.			Exposures.	Position angle.			Distance.		
				Observed.	Tabular.	Tab.−Obs.	Observed.	Tabular.	Tab.−Obs.
1899. d	h	m	m s.	°	°	°	″	″	″
Sept. 28	12	40	30 & 15	53·09	51·95	−1·14	14·37	14·41	+0·04
Oct. 10	12	3	30 & 20	42·67	39·57	−3·10	12·81	13·12	+0·31
12	12	11	30 & 10	261·23	261·88	+0·65	16·74	16·56	−0·18
16	11	40	30 & 10	32·27	32·55	+0·28	12·90	12·46	−0·44
1900. Jan. 17	10	2	20 & 10	(80·52)	83·08	(+2·56)	...	...	...
18	8	58	20 & 20	42·34	41·73	−0·61	14·45	13·81	−0·64
24	10	45	30 & 20	28·55	29·33	+0·78	12·35	12·49	+0·14

October 10. Image of planet elongated. January 17. Planet on edge of shutter.

Observations of Occultations of Stars by the Moon and Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the Year 1901.

(*Communicated by the Astronomer-Royal.*)

Day. 1901.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
March 26	Disapp. 68 Orionis	Astrographic Equat.	225	Dark	9 13 58·04	W.
April 22	,, Lalande 11088	Great Equat. (Corbett)	100	,,	9 25 20·88	H. F.
22 (*a*) (*b*)	,, χ^2 Orionis	Astrographic Equat.	225	,,	10 25 0·03	R.
23 (*a*)	,, W. B. (2) VI. 1200	Old Altazimuth	100	,,	8 5 54·76	A. C.
23 (*a*)	,, ,,	Sheepshanks Equat.	55	,,	8 5 54·85	W. B.
23	,, ,,	Astrographic Equat.	225	,,	8 5 54·57	S.
23	Reapp. ,,	Sheepshanks Equat.	55	Bright	8 23 59·51	W. B.
28 (*b*)	Disapp. p^2 Leonis	Great Equat.	670	Dark	10 42 18·68	B.
May 31	,, Piazzi XV. 96	Sheepshanks Equat.	120	,,	11 48 44·94	A. C.
June 4	Reapp. Lalande 35497	,, ,,	120	,,	12 41 47·97	B.
29	Disapp. Lalande 30725	Astrographic Equat.	225	,,	8 45 47·44	H.
July 28 (*b*)	,, 21 Sagittarii	,, ,,	225	,,	9 50 35·54	R.
Aug. 24 (*c*)	,, Piazzi XVII. 323	,, ,,	225	,,	8 46 48·78	G. B.
Oct. 22 (*d*)	,, c^1 Capricorni			,,	No Occultation	A. C., R.
23 (*b*) (*e*)	,, κ Aquarii	Great Equat.	670	,,	8 52 47·81	B.
27 (*e*)	,, 29 Arietis	Astrographic Equat.	225	Bright	12 14 58·90	H.
27 (*f*)	Reapp. ,,	,, ,,	225	App. Bright	13 7 24·02	H.

Day. 1901.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
Dec. 18	Disapp. λ Piscium	Great Equat.	670	Dark	7 23 57·86	B.
18	,, ,,	Sheepshanks Equat.	120	,,	7 23 57·80	W. B.
18	,, ,,	Great Equat. (Corbett)	120	,,	7 23 57·91	W. H. B.
18	Reapp. ,,	Great Equat.	670	Bright	8 7 40·59	B.
18 (*g*)	,, ,,	Sheepshanks Equat.	120	,,	8 7 (55)	W. B.

(*a*) The dark limb of the Moon was plainly visible.
(*b*) Instantaneous.
(*c*) Very faint; misty.
(*d*) This occultation was predicted in the *Nautical Almanac*, but did not actually occur, the star remaining visible throughout.
(*e*) Star appeared to glide up to and behind limb.
(*f*) Observer noted "possibly 0ˢ·5 late." The limb was apparently bright, the width of the dark lune being about 1″.
(*g*) The time was noted as "doubtful" by the observer, and is evidently erroneous.

Phenomena of Jupiter's Satellites.

Day. 1901.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of *N.A.* h m	Observer.
July 23	I.	Tr. Ing. First contact	Sheepshanks Equat.	100	9 35 6·29		H.
23	I.	Bisection	,, ,, ,,	,,	9 40 5·48	9 43	,,
23	I.	Last contact	,, ,, ,,	,,	9 44 14·79		,,
23	IV.	Occ. R. First seen	,, ,, ,,	,,	9 44 34·74		,,
23	IV.	Bisection	,, ,, ,,	,,	9 50 3 84	9 44	,,
23	IV.	Last contact	,, ,, ,,	,,	9 58 32 43		,,
24	I. (*a*)	Ec. R. First seen	Astrographic Equat.	225	9 51 47·36	9 52	R.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of *N.A.* h m	Observer.
1901. July 27	II.	Occ. D. First contact	Astrographic Equat.	225	10 12 45·02		H.
27	II.	Bisection	,, ,,	,,	10 16 14·45	10 15	,,
27	II.	Last seen	,, ,,	,,	10 18 54·00		,,
Aug. 7	I. (*b*)	Occ. D. First contact	,, ,,	,,	10 28 51·56		,,
7	I.	Bisection	,, ,,	,,	10 31 41·10	10 35	,,
7	I.	Last seen	,, ,,	,,	10 36 30·31		,,

(*a*) Limb unsteady, cloudy.

(*b*) Limb rather diffused and tremulous, but the observation considered good.

The apertures of the telescopes used are as follows :—

	inches.		inches.
Great Equatorial	28	Great Equatorial (Corbett Telescope) ...	6½
Astrographic Equatorial (Guiding Telescope)	10	Old Altazimuth	4
Sheepshanks Equatorial	6¼		

The initials H., A. C., B., W. B., R, H. F., W., S., G. B., W. H. B., are those of Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Bowyer, Mr. Rendell, Mr. Furner, Mr. Witchell, Mr. Showell, Mr. Bischlager, and Mr. Brookes respectively.

Royal Observatory, Greenwich: 1902 *January* 8.

Errata in Mr. Saunders' paper.

Vol. lx. page 189, lines 12, 21 (twice).

,, lxii. ,, 46, last line, and page 47, 8th line from bottom, *for* $(Dx - Ey)$ *read* $(Ex - Dy)$.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXII. FEBRUARY 14, 1902. No. 4

Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

William Ambrose Kibbler, M.B., Ashby House, 3 Manor Road, Stamford Hill, N.;
Charles F. Sandberg, M.A., Oxon, Lancing College, Shoreham, Sussex;
Albert Walter, Royal Alfred Observatory, Mauritius; and
Elward Fawcett White, Navigation Department, Merchant Venturers' Technical College, Bristol,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

George Herbert Bryant, Science Master, Hipperdale Schools, Cinderford, Gloucestershire (proposed by Albert Taylor);
Capt. G. P. Lenox-Conyngham, R.E., Survey of India, Mussoorie, India (proposed by Major E. H. Hills);
S. Alfred Mitchell, M.A. Ph.D., Tutor in Astronomy at Columbia University, New York City, U.S.A. (proposed by J. K. Rees);
James Rankine, 11 West Saville Road, Edinburgh (proposed by William Peck);
Thomas Thorp, Moss Bank, Whitefield, near Manchester (proposed by David G. Simpson); and
William Boultbee Whall, Younger Brother of the Trinity House, Nautical Surveyor, Board of Trade, Liverpool (proposed by M. J. O'Sullivan).

Report of the Council to the Eighty-Second Annual General Meeting of the Society.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron	Grand Total
1900 December 31	250	375	625	46	1	672
Since elected	+ 6	+22	...	+ 3	...	...
Deceased	− 6	− 7	...	− 3	...	...
Resigned	...	−11	...	...	...	...
Removals	...	...	...	...	...	...
Expelled	...	− 4	...	...	...	...
1901 December 31	250	375	625	46	1	672

Mr. Maw's Report as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, 1901 January 1:—						
At Bankers', as per Pass-book	535	4	4			
Cheque not credited till 1901	4	4	0			
In hand of Assistant Secretary on Petty Cash Account	10	4	6			
				549	12	10
Dividends on £1,250 Metropolitan 3-per-cent. Stock	35	7	11			
Dividends on £932 19 0 Metropolitan 2½-per-cent. Stock	22	0	4			
Dividends on £3,400 East Indian Railway 3-per-cent. Debenture Stock	96	5	3			
Dividends on £3,200 London and North-Western Railway 3-per-cent. Debenture Stock	91	0	0			
Half-year's Dividend on £3,600 Midland Railway 2½-per-cent. Debenture Stock	42	15	0			
Half-year's Dividend on £4,000 Midland Railway 2½-per-cent. Debenture Stock	47	5	10			
Dividends on £1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock	52	17	10			
Dividends on £1,100 Commercial Gas Co. 4½-per-cent. Debenture Stock	46	14	3			
Interest on £300 on Deposit at Bankers'	3	0	7			
				437	7	0
Received on account of Subscriptions:—						
Arrears	165	18	0			
Annual Contributions for 1901	613	4	0			
„ „ 1902	6	6	0			
Admission Fees	63	0	0			
First Contributions	35	14	0			
				884	2	0
Composition Fees				126	0	0
Sales of Publications:—						
At Williams and Norgate's, 1900	11	5	7			
At Society's Rooms, 1901	73	10	3			
Sales of Photographs, 1901	28	9	6			
				113	5	4
Income Tax refunded by Commissioners of Inland Revenue				21	8	9
Cheques outstanding 1901 December 31				16	19	6
Due to Assistant Secretary on Petty Cash Account				1	19	3
				£2,150	14	8

Examined and found correct, 1902 Jan. 8:
W. B. GIBBS, H. P. HOLLIS, F. W. LEVANDER.

Astronomical Society, from 1901 *January* 1 *to December* 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
„ „ for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
House Duty	2	12	6			
Fire Insurance	9	9	6			
				12	2	0
Printing *Monthly Notices*	459	12	8			
„ Appendix to *Monthly Notices*	30	3	0			
„ „ *Memoirs*	14	10	0			
„ Supplementary Library Catalogue ...	64	18	9			
„ List of Fellows, Charter and Bye-Laws, and Miscellaneous	23	19	0			
				593	3	5
Computation of Ephemerides in *Monthly Notices* ...				15	0	0
Turnor and Horrox Funds: Purchases for Library	21	9	10			
Folios and mounts for drawings in Library ...	6	2	6			
				27	12	4
Reproduction of Photographs				21	12	8
Cataloguing astronomical literature for the International Catalogue of Scientific Literature ...				30	0	0
Clerk's Wages	52	0	0			
Postage and Telegrams	84	8	3			
Carriage of Parcels, &c.	3	5	2			
Stationery (Spottiswoode & Co.)	4	4	6			
Sundry Stationery and Office Expenses	3	7	4			
				147	5	3
Expenses of Meetings	20	0	0			
Lantern Expenses	10	15	0			
Time Signal, &c.	6	10	0			
				37	5	0
House Expenses	67	1	10			
Coals and Gas	53	18	11			
Electric Light Expenses	9	13	4			
Furniture, Repairs, &c.	9	13	10			
Sundry Fittings and Repairs	9	18	11			
Sundries	7	1	5			
				157	8	3
Illuminating Address to His Majesty	5	13	0			
Gold Medals	52	10	0			
				58	3	0
Purchase of £400 Midland Railway 2½-per-cent. Debenture Stock				340	12	6
Cheque-book and deductions on Cheques					11	9
Repayment to Assistant Secretary of amount due 1901 Jan. 1 on account of Turnor and Horrox Funds				2	0	11
Balances, 1901 December 31:—						
At Bankers', as per Pass-book	101	8	4			
„ „ on deposit	300	0	0			
In hand of Assistant Secretary on account of Turnor and Horrox Funds	6	9	3			
				407	17	7
				£2,150	14	8

Report of the Auditors.

We have examined the Treasurer's accounts of receipts and expenditure for the year 1901, and have found and certified the same to be correct. The cash in hand on December 31, 1901, including the balance at the bankers', &c., amounted to £407 17*s.* 7*d.*

During the past year the sum of £340 12*s.* 6*d.* has been invested in the purchase of £400 Midland Railway 2½ per cent. Debenture Stock.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

We wish to call the attention of the Society to the fact that there are now 250 compounding Fellows out of a total number of 625; and that in our opinion it would be conducive to the interests of the Society that the composition fee should be increased.

(Signed) W. B. GIBBS,
H. P. HOLLIS,
F. W. LEVANDER.

Trust Funds.

The Turnor Fund: A sum of £464 18*s.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £103 6*s.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £334 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given by the Council to the widow or orphan of any deceased Fellow of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £309 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in Medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1902 January 1.

	£	s.	d.	£	s.	d.
Balances, 1901 December 31:—						
At Bankers', as per Pass-book	101	8	4			
„ „ on deposit	300	0	0			
In hand of Assistant Secretary on account of Turnor and Horrox Funds	6	9	3			
	407	17	7			
Less due to Assistant Secretary on Petty Cash Account £1 19 3						
Less due to Cheques outstanding 16 19 6						
	18	18	9			
				388	18	10
Due on account of Subscriptions:—						
1 Contribution of 5 years' standing	10	10	0			
2 Contributions of 4 „	16	16	0			
10 „ 3 „	63	0	0			
18 „ 2 „	75	12	0			
61 „ 1 year's standing	128	2	0			
	294	0	0			
Less 3 Contributions paid in advance ...	16	6	0			
				287	14	0
Due from Williams and Norgate for sales of Publications during 1901				13	16	4
£3,400 East Indian Railway 3-per-cent. Debenture Stock, including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (née Gwilt) Fund.						
£3,200 London and North Western Railway 3-per-cent. Debenture Stock.						
£4,000 Midland Railway 2½-per-cent. Debenture Stock.						
£1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock.						
£1,100 Commercial Gas Company 4½-per-cent. Debenture Stock.						
£1,250 Metropolitan 3-per-cent. Stock.						
£932 19 0 Metropolitan 2½-per-cent. Stock.						
Astronomical and other Manuscripts, Books, Prints, and Instruments.						
Furniture, &c.						
Stock of Publications of the Society.						
Five Gold Medals.						

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	8	...	XXXII.	145	...
I. Part 2	42	...	XXXIII.	154	...
II. Part 1	51	3	XXXIV.	156	...
II. Part 2	16	3	XXXV.	104	1
III. Part 1	65	1	XXXVI.	187	8
III. Part 2	82	1	XXXVII. Part 1	330	7
IV. Part 1	77	3	XXXVII. Part 2	278	8
IV. Part 2	89	3	XXXVIII.	263	1
V.	100	3	XXXIX. Part 1	228	2
VI.	117	6	XXXIX. Part 2	233	2
VII.	140	3	XL.	248	...
VIII.	124	3	XLI.	392	1
IX.	130	3	XLII.	224	3
X.	142	...	XLIII.	221	...
XI.	147	...	XLIV.	205	1
XII.	152	...	XLV.	238	...
XIII.	150	...	XLVI.	214	2
XIV.	358	...	XLVII. Part 1	2	...
XV.	131	...	XLVII. Part 2	18	...
XVI.	157	1	XLVII. Part 3	2	...
XVII.	140	1	XLVII. Part 4	8	...
XVIII.	132	1	XLVII. Part 5	8	...
XIX.	143	...	XLVII. Part 6	9	...
XX.	133	1	XLVII.	194	1
XXI. Part 1	244	...	XLVIII. Pt. 1	226	1
XXI. Part 2	98	...	XLVIII. Pt. 2	227	1
XXI.	54	...	XLIX. Part 1	352	...
XXII.	156	...	XLIX. Part 2	236	2
XXIII.	141	...	L.	226	2
XXIV.	147	1	LI.	257	...
XXV.	153	...	LII.	307	...
XXVI.	163	1	LIII.	322	1
XXVII.	417	1	LIV. App. I.	716	...
XXVIII.	371	...	App. II.	745	...
XXIX.	395	1	Index to *Memoirs*	619	2
XXX.	147	1			
XXXI.	134	...			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	53	...	XXXIII.	86	...
II.	55	...	XXXIV.	65	1
III.	...	...	XXXV.	51	...
IV.	...	...	XXXVI.	25	1
V.	...	...	XXXVII.	31	3
VI.	40	...	XXXVIII.	95	1
VII.	2	...	XXXIX.	95	...
VIII.	151	2	XL.	103	3
IX.	23	3	XLI.	103	5
X.	170	1	XLII.	111	1
XI.	181	...	XLIII.	108	2
XII.	104	1	XLIV.	110	2
XIII.	176	2	XLV.	114	1
XIV.	175	3	XLVI.	107	...
XV.	167	2	XLVII.	122	2
XVI.	152	1	XLVIII.	117	...
XVII.	164	...	XLIX.	108	7
XVIII.	242	...	L.	108	9
XIX.	51	...	LI.	110	6
XX.	31	...	LII.	107	10
XXI.	16	...	LIII.	111	13
XXII.	30	...	LIV.	109	13
XXIII.	17	...	LV.	122	...
XXIV.	22	...	LVI.	120	2
XXV.	13	...	LVII.	127	2
XXVI.	9	...	LVIII.	124	...
XXVII.	3	...	LIX.	129	3
XXVIII.	70	...	LX.	133	4
XXIX.	50	...	LXI.	150	...
XXX.	61	2	1st Index ...	541	1
XXXI.	90	...	2nd „ ...	796	...
XXXII.	106	5			
LIBRARY CATALOGUE				540	2
„ „ SUPPLEMENT				422	...

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly

all the volumes. With the exception, however, of Vols. XXXVI. to LXI., no complete volumes can be formed from the separate numbers in stock.

Celestial Photographs.

The following is a list of reproductions of Celestial Photographs published by the Royal Astronomical Society for sale to the Fellows :—

R.A.S. Ref. No.	Subject.	Photographed by
1	Total Solar Eclipse, 1889 January 1	W. H. Pickering
2	Total Solar Eclipse, 1893 April 16	J. M. Schaeberle
3	Total Solar Eclipse, 1886 August 29	A. Schuster
4	Nebulæ in the *Pleiades*	Isaac Roberts
5	Nebula M 74 *Piscium*	Isaac Roberts
6	Great Nebula in *Orion*	Isaac Roberts
7	Milky Way near M 11	E. E. Barnard
8	Milky Way near Cluster in *Perseus*	E. E. Barnard
9	Comet *c* 1893 IV. (Brooks), 1893 October 21	E. E. Barnard
10	Comet *a* 1892 I. (Swift), 1892 April 7	E. E. Barnard
11	Nebula about η *Argûs*	David Gill
12	Portion of Moon (Hyginus-Albategnius)	Loewy and Puiseux
13	Comet *c* 1893 IV. (Brooks), 1893 October 22	E. E. Barnard
14	Comet *c* 1893 IV. (Brooks), 1893 October 20	E. E. Barnard
15	Comet *c* 1893 IV. (Brooks), 1893 November 10	E. E. Barnard
16	Comet *a* 1892 I. (Swift), 1892 April 26	E. E. Barnard
17	Comet *f* 1892 III. (Holmes), 1892 November 10	E. E. Barnard
18	Comet *a* 1892 I. (Swift), 1892 April 18	E. E. Barnard
19	Portion of Moon (Alps, Apennines, &c.)	Loewy and Puiseux
20	Nebula in *Andromeda*	Isaac Roberts
21	*Jupiter*, 1892 September 26	Lick Observatory
22	Cluster M 13 *Herculis*	W. E. Wilson
23	Total Solar Eclipse, 1893 April 16 (5 sec.)	J. Kearney
24	Total Solar Eclipse, 1893 April 16 (20 sec.)	J. Kearney
25	The Moon (Age 7^d 3^h)	Lick Observatory
26	The Moon (Age 12^d $6\frac{1}{2}^h$)	Lick Observatory
27	The Moon (Age 16^d 18^h)	Lick Observatory
28	The Moon (Age 23^d 8^h)	Lick Observatory

R.A.S. Ref. No.	Subject.	Photographed by
29	The Sun, 1892 February 13	Roy. Obs., Greenwich
30	The Sun, 1892 July 8	Roy. Obs., Greenwich
31	Portion of Moon (Region of Maginus)	Lœwy and Puiseux
32	The Moon (Age 14^d 1^h)	Lick Observatory
33	Portion of Moon (Ptolemæus, &c.)	Lick Observatory
34	Portion of Moon (Mare Serenitatis)	Lick Observatory
35	Portion of Moon (Clavius, Licetus, &c.)	Lick Observatory
36	Portion of Moon (Regiomontanus, &c.)	Lick Observatory
37	Portion of Moon (Tycho, Thebit, &c.)	Lick Observatory
38	Portion of Moon (Theophilus, &c.)	Lick Observatory
39	Total Solar Eclipse, 1896 August 9 (3 sec.)	S. Kostinsky
40	Total Solar Eclipse, 1896 August 9 (26 sec.)	A. Hansky
41	Cluster M 56 *Lyræ*	
42	Nebulæ M 81, 82 *Ursæ Majoris*	
43	Cluster M 56 *Lyræ* (enlarged)	
44	Solar Corona, 1871 December 12, Baikul	H. Davis
45	Solar Corona, 1875 April 6, Siam	Lockyer and Schuster
46	Solar Corona, 1878 July 29, Wyoming	W. Harkness
47	Solar Corona, 1882 May 17, Egypt	Abney and Schuster
48	Solar Corona, 1883 May 6, Caroline Island	Lawrance and Woods
49	Solar Corona, 1885 September 9, Wellington, N.Z.	Radford
50	Solar Corona, 1886 August 29, Grenada, W.I.	A. Schuster
51	Solar Corona, 1887 August 19, Japan	M. Sugiyama
52	Solar Corona, 1889 January 1, California	W. H. Pickering
53	Solar Corona, 1889 December 22, Cayenne	J. M. Schaeberle
54	Solar Corona, 1893 April 16, Fundium	J. Kearney
55	Solar Corona, 1893 April 16, Brazil	A. Taylor
56	Great Nebula in *Orion*	W. E. Wilson
57	Dumb-bell Nebula, *Vulpeculæ*	W. E. Wilson
58	Spiral Nebula, *Canes Venatici*	W. E. Wilson
59	Spiral Nebula, *Canes Venatici* (enlarged)	W. E. Wilson
60	Annular Nebula, *Lyræ*	W. E. Wilson
61	Meteor Trail and Comet Brooks, 1893 November 13	E. E. Barnard
62	Total Solar Eclipse, 1898 January 22 (5 sec.)	W. H. M. Christie
63	Total Solar Eclipse, 1898 January 22 (20 sec.)	W. H. M. Christie
64	Solar Corona, 1896 August 9, Novaya Zemlya	G. Baden-Powell
65	Solar Corona, 1898 January 22, Pulgaon, India	E. H. Hills
66	Nebula in *Andromeda*	Roy. Obs., Greenwich
67	Spectrum of Sun's limb, 1898 January 22	E. H. Hills

R.A.S. Ref. No.	Subject.	Photographed by
68	Annular Nebula, *Lyra*	Lick Observatory
69	Dumb-bell Nebula, *Vulpecula*	Lick Observatory
70	Spiral Nebula, *Canes Venatici*	Lick Observatory
71	Spiral Nebula, *Ursa Major*	Lick Observatory
72	Trifid Nebula, *Sagittarius*	Lick Observatory
73	Great Nebula in *Orion*	Lick Observatory
74	Cluster M 13 *Herculis*	Lick Observatory
75	Solar Surface with Faculæ	G. E. Hale
76	Faculæ and Prominences	G. E. Hale
77	Total Solar Eclipse, 1898 Jan. 22 (¾ sec.)	W. H. M. Christie
78	Nebula H V. 14 *Cygni*	W. E. Wilson
79	Portion of Moon (Theophilus, &c.)	Yerkes Observatory
80	Total Solar Eclipse, 1900 May 28 (30 sec.)	E. E. Barnard
81	Comet 1901 I., 1901 May 4	Roy. Obs., Cape of G. H.
82	Comet 1901 I., 1901 May 6	Roy. Obs., Cape of G. H.
83	Comet 1901 I., 1901 May 9	Perth Obs., W. Australia
84	Solar Surface with Faculæ	H. Deslandres
85	Solar Prominences	H. Deslandres

Nos. 44–55 and Nos. 64 and 65 form a series of corona photographs, oriented and reduced to the same scale.

The above photographs are now on sale to Fellows as prints, either platinotype or aristotype, mounted on sunk cut-out mounts, measuring 12 inches by 10 inches, and also as lantern slides. Nos. 44–55 and Nos. 64 and 65 are also supplied as transparencies, 6¼ inches square.

Price of prints, 1*s.* 6*d.* each; lantern slides, 1*s.* each; packing and postage extra.

Unmounted prints, 1*s.* each, can be obtained to order.

Transparencies, 6¼ inches square (Nos. 44–55 and Nos. 64 and 65), 3*s.* 6*d.* each.

Orders to be addressed to W. H. Wesley, Burlington House, London, W. In ordering prints or slides the R.A.S. Reference No. only need be quoted, but in the case of prints it should be stated whether platinotypes or aristotypes are required.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatorial.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatorial.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatorial, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.
„ 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

No. 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Y's for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, reading to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y-piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

No. 47. (21) Box sextant; reflecting plane and level.
„ 48. (22) Prismatic compass, by Troughton and Simms.
„ 49. (23) Mountain barometer.
„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.
„ 51. (25) Ordinary 4½-inch compass with needle.
„ 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.

No. 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
„ 87. 3½-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.
„ 91. Astronomical time watch-case, by Professor Chevallier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 117. Two old sun-dials.
„ 118. A 10½-inch sixteenth-century celestial globe, on bronze tripod stand.
„ 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.

No. 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-inch portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere.
„ 130. 10-inch brass pillar sextant with counterpoise stand, by Troughton.
„ 131. Double box sextant, by Cary.
„ 132. Equatorially mounted camera with 2½-inch portrait lens and telephotographic enlarging lens by Dallmeyer; iron pillar.
„ 133. 3¼-inch equatorial by Ross, with tall tripod stand, equatorial mounting, eyepieces, and micrometer.
„ 134. Old transit instrument, 2-inch aperture and 3 feet focal length (without stand), formerly belonging to Dr. Longfield, of Cork.
„ 135. Globe of Mars, by E. M. Antoniadi.
„ 136. A small universal instrument by W. and S. Jones, London; the telescope 1½-inch aperture and 15 inches focal length. [Presented by Miss Moore.]
„ 137. Polar siderostat by Hilger, with 4½-inch mirrors. [Presented by Mr. Alexr. Foote.]
„ 138. Transit instrument, aperture 2¼-inch, with collimator and stand. [Presented by Mrs. Cross.]
„ 139. Transit instrument, aperture 1½-inch, with portable stand. [Presented by Mrs. Cross.]
„ 140. 3½-inch object-glass and tube. [Presented by Mrs. Cross.]

Besides the above, there is the following apparatus available for eclipse work:—

4 Slits for spectroscope.
Abney doublet lens used in photographing the corona.
2 Dallmeyer negative enlarging lenses.
Cœlostat with 16-inch plane mirror.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.

No. 22. The *Matthew* equatorial, to Mr. C. Thwaites.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 28. (2) 6-inch theodolite and stand, to Dr. A. A. Common.
„ 29. (3) Equatorial mounting, clock, &c., to the Rev. C. D. P. Davies.
„ „ Wire micrometer (No. 2), to the Rev. C. D. P. Davies.
„ 30. (4) 3¼-inch equatorial and stand, to Mr. C. H. Johns.
„ „ Double-image micrometer, to the Rev. W. J. B. Roome.
„ 57. (31) Box sextant, to Dr. A. A. Common.
„ 69. (43) Telescope with rock-crystal object-glass, to Sir W. Huggins.
„ 72. (*c*) Polarimeter, to Professor C. Michie Smith.
„ 78. 9¼-inch reflector and stand, to the Rev. W. J. B. Roome.
„ 80. Box of polariscopic apparatus, to Mr. H. F. Newall.
„ 98. 2-foot 6-inch navy telescope, to the Rev. J. M. Bacon.
„ 123. 6-inch telescope, by Grubb (object-glass only), to Mr. W. E. Wilson.
„ 125. 6-inch refractor, by Simms, to Dr. A. A. Common.
„ 133. 3¼-inch equatorial, by Ross, to Dr. A. W. Roberts.

Award of Medals.

The Council have awarded the Society's Gold Medal to Professor J. C. Kapteyn, for his work in connection with the Cape Photographic Durchmusterung, and his researches on stellar distribution and parallax. The President will lay before the Society the grounds upon which the award has been founded.

The Hannah Jackson (née Gwilt) Gift and Bronze Medal have been awarded to the Rev. Thomas D. Anderson for his discovery of *Nova Aurigæ* and *Nova Persei*.

Reprinting of Astronomical Papers from the Publications of the Royal Society.

By the courtesy of the Royal Society permission has been granted to the Council of the Royal Astronomical Society to issue to the Fellows, in the form of Appendices to the *Memoirs* and *Monthly Notices*, papers of astronomical interest which appear in the *Philosophical Transactions* and *Proceedings* of the

Royal Society. The Council of the Royal Society have also further kindly arranged that notice be sent to the Royal Astronomical Society as soon as papers which might be required are in type, so that the additional copies for the Appendices to the *Memoirs* or *Monthly Notices* can be obtained before the type is distributed, the Royal Astronomical Society paying for the cost of striking off the additional copies.

During the past year four numbers of Appendix to vol. lxi. of the *Monthly Notices* have been published, containing, amongst others, a series of papers on *Nova Persei*, by Sir Norman Lockyer; and one Appendix to vol. lxii., containing the preliminary reports of the observers of the total solar eclipse of 1901.

The following Appendices to vol. liv. of the *Memoirs* have also been issued:

I. Sir Norman Lockyer, Total eclipse of the Sun, 1898 January 22; observations at Viziadrug.

II. J. Evershed, Wave-length determinations and general results obtained from a detailed examination of spectra photographed at the solar eclipse of 1898 January 22.

Address to His Majesty.

The Council have pleasure in announcing that His Majesty King Edward VII. was graciously pleased to accept the Address of condolence and homage, the text of which was printed on p. 181 of last year's Annual Report. The Address was presented by the President and Secretary, and was received by His Majesty in person at St. James's Palace on March 20, 1901.

On April 18 a letter was received by the President from General Sir D. Probyn, Keeper of H.M. Privy Purse, announcing that His Majesty had graciously consented to become the Patron of the Society.

Obituary.

The Council regret that they have to record the loss by death of the Society's gracious Patron Her late Majesty Queen Victoria and of the following Fellows and Associates during the past year :—

Fellows :—Rev. J. Chadwick Bates.
E. E. Bowen.
*John Brett.
Rev. R. Crowe.
Major-Gen. A. W. Drayson.
J. P. Hartree.
Lord Inverclyde.
S. Wellesley Johnson.
William Lethbridge.
†D. L. Lowson.
Charles Meldrum.
John Parnell.
Sir Cuthbert E. Peek.
B. Woodd Smith.

Associates :—H. A. Rowland.
T. H. Safford.
Wilhelm Schur.

J. Chadwick Bates was born on the 17th of June 1826 at Oldham. He was educated at Manchester Grammar School and Queen's College, Oxford. He was ordained by the Bishop of Manchester in 1850. From 1851 to 1856 he had a curacy at Hull, and for the last 43 years his life was closely interwoven with the history of the village of Castleton, of which he was vicar. His first interests were in the welfare of his church, schools, and the public affairs of his parish. When he went to Castleton it was a small village, and he was appointed curate in charge of a small mission chapel by the Vicar of Rochdale. He soon started a movement towards building a church, and by 1862 St. Martin's Church had been built at a cost of 3,000*l*. During the 43 years Mr. Bates was Vicar of Castleton no less than 16,000*l*. was raised for parochial objects.

* Although Mr. Brett died subsequently to December 31, 1901, an account of his life is given in this year's Report.

† Removed from List as deceased, his name having been in the List of Fellows without address for eighteen years.

Mr. Bates took a deep interest in several branches of science, particularly astronomy, meteorology, and geology. He had a well-equipped meteorological station in the vicarage garden and kept a careful record of the rainfall, temperature, &c. He was a Fellow of the Geological Society as well as of the Royal Astronomical Society, to which he was elected on the 13th of November 1863. Mr. Bates possessed considerable mechanical skill, and constructed almost entirely with his own hand the dome over his equatorial. He built a room for his transit instrument himself, and he also carved parts of the stonework of the church.

Mr. Bates married a Miss Jackson, of Hull, who died in 1874. They had one son and four daughters. He died on the 14th of December 1901, at St. Martin's Vicarage after a short illness.

Edward Ernest Bowen was born in 1836, being the second son of the Rev. Christopher Bowen, sometime Vicar of St. Thomas's, Winchester; his elder brother was the late Lord Bowen, the well-known Judge. Edward Bowen went up from King's College, London, to Trinity College, Cambridge, in 1854; he was a Bell Scholar for 1855. In 1858 he was fourth in the Classical Tripos, and shortly afterwards obtained a Fellowship at Trinity. He left Cambridge soon after to become a master at Harrow, where the rest of his life was spent unreservedly and whole-heartedly for the welfare of the school and in the service of his pupils. His brilliant intellect, sound judgment, and unlimited kindness made him an ideal schoolmaster.

Many who have never seen him have been charmed by his school songs. "Forty Years On" has long been classical, and is known far beyond the bounds of Harrow.

A typical Bowenite institution at Harrow was "astronomy." Every boy in his house had to attend two courses of lectures before he left—one astronomy, the other the history of a war—but both were called by the boys "astronomy." Each Christmas term, for one evening in every week, the astronomers (roughly speaking, the middle-sized boys of the house) were gathered in his drawing room, and, if it was astronomy proper, he explained the courses of the heavens by aid of a little round table that was the Sun, a cricket-ball that was the Moon, putting them through their various motions in the centre of the room. Sometimes he himself actively personified the Moon or some other heavenly body, while the boys sat round critically spectatorial. The boys had no function but to look on, but evil waited on him who did not understand and remember.

Mr. Bowen died on the 8th of April at Moux, in the Côte-d'Or, France, while on a bicycling tour. He was to all appearance in perfect health, but fell while mounting his machine and never recovered consciousness.

He was elected a Fellow of the Astronomical Society on the 8th of February 1867.

JOHN BRETT was born at Reigate on the 8th of December 1831. He was an artist of eminence, and was elected an Associate of the Royal Academy in 1881. "In early life" (to quote the *Times* of the 9th of January) "he came strongly under the influence of the Pre-Raphaelite movement. Over an early picture of his, *The Stonebreaker*, Ruskin grew enthusiastic. 'It is a marvellous picture,' he wrote, 'and may be examined inch by inch with delight;' and again, 'I know no such thistle-down, no such chalk hills and elm trees, no such natural pieces of far-away cloud.' This picture was exhibited at the Royal Academy in 1858. In the following year Brett showed his famous *Val d'Aosta*, in which he endeavoured, not without success, to carry out the principles of the pre-Raphaelites in landscape-painting. Very few artists have tried to do this, though Holman Hunt, in addition to Brett, showed that the aims of the school could be illustrated by landscape as well as by romantic figure pictures." Perhaps the most famous of the many pictures of sea and coast scenery which he painted later was his *Britannia's Realm*, a simple stretch of open sea, which nevertheless fascinated the attention; it was exhibited at the Royal Academy in 1880, and purchased by the Trustees of the Chantrey Bequest. He continued to paint and exhibit up to the closing years of his life, and died at the ripe age of 70 on the 7th of January 1902.

Mr. Brett was a devoted astronomer throughout his life. "I think he was about thirteen or fourteen years old," writes his brother, "when he *bought* his first telescope, and that was a 3-inch reflector. I remember it well. Before that time he had always made up his telescopes of such pieces as he could collect at second-hand shops. From the 3-inch reflector he went to a 6-inch; and when he was sixteen, or perhaps seventeen, he made his 9-inch telescope, casting its speculum in the disused coach-house at home, and grinding it and polishing it on a machine in his painting-room. Many a halfpenny I earned turning the handle. He was well convinced of the disadvantages appertaining to any tubular connection between the speculum and the eye-piece; and that 9-inch reflector had no tube, the connection being by a stout beam or bar of wood at one side; and in his last 11-inch Browning reflector the same principle is carried out. Currents of air and needless vibrations are thus avoided."

Mr. Brett was elected a Fellow of this Society on the 9th of June 1871. Just previously he had been out to Sicily with the expeditions to observe the total solar eclipse of the 21st of December 1870, and had made observations, of which he gave a clear account (*Monthly Notices*, xxxi., p. 163) and several drawings. He states what he saw with an independence and fearlessness which his subsequent papers showed to be characteristic. "The appearance (near the limb), on the whole, was far more like terrestrial conflagration than I expected, especially (in a footnote) the combustion of wood in a baker's oven when nearly exhausted.

. . . . I must confess I was extremely vexed not to see anything like the corona I expected; I should never have called this a corona at all. . . . . There were certainly no streamers, so I conclude they must have been intercepted by the cloud. I do not mean merely that their light was, but their cause also. . . . . I conclude that the dew which would have formed streamers was, at Augusta, intercepted or prevented by cloud; although the latter was not dense enough to conceal much." (*Monthly Notices*, xxxi., pp. 165–6.) We now know that this conclusion as to the terrestrial nature of the streamers was incorrect; but Mr. Brett, no doubt, recorded very faithfully what he saw. His trained eye was a most effective astronomical weapon, and his actual observations are deserving of every respect, though when he proceeded to draw deductions he is more open to criticism.

At this same eclipse he noticed a "ray or cone of light emanating from the south (later, also the north) cusp in a direction tangential to the Moon's limb, length not more than 3′: light less intense than that of the cusp, but as beautifully defined as anything I ever saw in my life." At the partial eclipse on the 10th of October 1874 he saw the same phenomenon on a much smaller scale, and made the suggestion of a lunar atmosphere, which is only of appreciable density in the deepest valleys. This is not the place to discuss the conclusion, but the observations are well worthy of note; as also those from which Mr. Brett concluded that indications of the corona could be seen without an eclipse (*Monthly Notices*, xxxii., 297).

His other observations (made at his residence at Putney, chiefly with the Browning reflector above mentioned, for which he devised a simple but firm altazimuth mounting, though he had, also, the Matthew Equatorial on loan from this Society for many years) were of planetary detail, and called attention to several points of great importance. He observed that the white spots on *Jupiter* were either themselves shaded or cast a shadow, and concluded that "neither the dark belts nor the bright ones are opaque, and that if *Jupiter* has any nucleus at all it is not visible to us." He observed that the brightest point of the disc of *Venus* was not at the limb, but sensibly within the limb, indicating that there was specular reflection from its surface largely modified by atmospheric diffusion. And, finally, he observed shadows cast by the polar caps of *Mars*, and concluded that they were not snow, but cloud.

These observations met with almost a storm of incredulity in some quarters when communicated to the Society. "One is tempted to ask," wrote the late Mr. R. A. Proctor to the *Astronomical Register* (vol. xv., page 45), "what is coming to the Royal Astronomical Society when such a paper as Mr. Brett's, on the bright ring seen round *Venus* during transit, is allowed by the Council to be read before a meeting of the Fellows? . . . All that the spectroscope has taught us, all that we have learned of meteoric and cometic systems and of the laws of cosmical

evolution, the laws of optics, and in fine the teachings of every department of modern astronomy, seem of no weight whatever with the excellent artist whose paintings of Scilly scenery delighted us so much a year or so since. Not content with seeing the corona in the full blaze of sunlight, and setting globes as large as the Earth bobbing in the atmosphere of *Jupiter*, he would now set astronomers to look during the transit of *Venus* in 1882 for an image of the Earth reflected in *Venus's* looking-glass! What next? and next?" They were times when views were expressed with considerable frankness within the Society; and Mr. Brett himself, it may be acknowledged, was one of those who spoke his mind most directly. But those who, instead of ridiculing an observation because it announced a new fact, took the trouble to test it by observation themselves, generally found that Mr. Brett's keen sight had not misled him. The present Astronomer Royal tested the announcement of specular reflection from *Venus* by an independent method with the 13-inch Merz refractor, and verified it; and he followed Mr. Brett in his explanation of the bright ring seen round *Venus* in transit as due to specular reflection modified by atmospheric diffusion. The observations on *Mars* have been corroborated, though differently interpreted; for other observers have seen a dark border to the caps and called it melted snow. The shadows cast by white spots on *Jupiter* were confirmed by M. Faye in a paper read to the French Academy in 1876; and, as regards seeing the corona in daylight, M. Tacchini recorded an even more remarkable observation in 1879 (*Observatory*, vol. ii., page 423). Recently more attention has been paid to the photography of the corona without an eclipse than to eye observation of it. If in the future our attention is recalled to eye observations, Mr. Brett may again be found to be right. His own generation, though his observations came as a shock to them, were not lacking in recognition of his merits. He was elected on the Council in 1876 and again in 1877. As a "sign of the times," it may be recalled that the scrutineers were only able to announce the Council list in 1877 after an absence of two hours and a half. Mr. Brett was constantly at the meetings of the Society until the last ten years, when his failing health prevented attendance; and his characteristically emphatic remarks were a well-known element in the discussions. Almost his last appearance was in April 1892, when Captain (now Sir William) Abney read a paper on the extinction of star-light with a wedge, and talked of the fatigue caused by looking at different colours, saying that looking at red for some time rendered the red nerves useless. "You can look at the green till all is blue, sir!" interjected Mr. Brett, and Captain Abney at once acknowledged the aptness of the remark.

In his paintings Mr. Brett found greater scope for exact appreciation of meteorological than of astronomical phenomena; but in one of his great pictures, "Summer Sunset in the Hebrides,"

painted in 1880, he shows how the Sun may be painted the right size (usually it is grossly exaggerated in pictures) and yet produce the right effect on the casual observer. He made a sketch of the great comet of 1882, which was reproduced in the *Monthly Notices* (vol. xliii., page 288); and a "rough drawing of *Copernicus*," made with the Matthew Equatorial in 1876, forms the frontispiece to vol. i. of the *Observatory*. H. H. T.

ROBERT CROWE was born at Middleton, in the Yorkshire Wolds, on the 19th of December 1820. He obtained the degree of Master of Arts at Trinity College, Dublin, and shortly afterwards took Holy Orders. For 47 years, from 1851 to 1898, he was Vicar of Woodhouse, near Huddersfield. He made his own telescopes and was a regular observer of the planets. He became a Fellow of the Society in 1869.

He married a daughter of the Rev. C. Drawbridge, a former vicar of Honley, near Huddersfield. They had no children. He died at Woodhouse Vicarage on the 9th of November 1901.

ALFRED WILLIAM DRAYSON was born at Waltham Abbey, Essex, in 1827. He received his education at the Royal Military Academy, Woolwich, and obtained his first commission in 1846. He served in the Kaffir war in 1847, and against the insurgent Boers in 1848. In both campaigns his knowledge of the Kaffir and Zulu languages were of great service. He was appointed instructor in surveying and field works at the Royal Military Academy, Woolwich, and shortly afterwards professor of surveying and practical astronomy. During this period he was instructor to the Duke of Connaught. On returning to military duty he was appointed to command the Royal Artillery at Portsmouth. In 1876 he proceeded to India in command of his brigade, and did valuable work in the rearmament of various forts in Bengal. Upon returning to England he was promoted to the rank of General. He retired from the army in 1883, and lived at Southsea till his death on the 27th of September 1901.

General Drayson wrote a number of stories, beginning in 1858 with *Sporting Scenes among the Caffres*, and following with *Among the Zulus*, *The Gentleman Cadet*, and many others. He published books on billiards and whist, on both of which games he was an authority.

As a military writer mention may be made of his work on military surveying, which had several editions and was used as a text-book.

In his astronomical writings General Drayson went somewhat astray. In one of these he attributed what were really errors of observation to a gradual increase of the Earth's diameter; and in another he substituted a geometrical movement of the pole (which more or less accounted for the phenomena of recent years, but which was entirely empirical) for the orthodox precession,

nutation, and change in inclination of ecliptic to equator, which have a dynamical basis.

General Drayson was of a kindly disposition and made many friends. He passed a long life in great activity and rendered valuable services to his country.

He was elected a Fellow of the Society on the 10th of January 1868.

JOHN PENN HARTREE was born at Lewisham on the 14th of November 1844, and died at his residence at Cambridge on the 3rd of May 1901. He entered at Trinity College, Cambridge, in 1863, and obtained a first class in the Natural Science Tripos in 1865. After taking the degrees of M.A. and M.B. he practised for some years as a doctor, but retired from practice in 1875. His practical interest in astronomy began in 1876 and continued till 1896; he possessed a 6-inch Cooke equatorial, a small transit by Troughton and Simms, and an astronomical clock. He was elected a Fellow of the Society in 1879, but never communicated any papers. He married in April 1868 Janet, eldest daughter of Samuel Smiles, LL.D.; his wife died in 1899. They leave two sons, a daughter having died in childhood.

LORD INVERCLYDE, better known perhaps as Sir John Burns, was born in Glasgow in 1829. He was the eldest son of Sir George Burns, Bart., of Wemyss Bay, and Jane, daughter of James Cleland, LL.D., of Glasgow. He was educated at Glasgow University, and immediately after leaving college was associated with his father in the business of the Cunard Steamship Company.

On the retirement of the original partners he became head of the company, and its present great position has been attained through his foresight and enterprise. In addition to the great development of the Cunard Line he greatly improved the mail service between Scotland and Ireland by his fine fleet of Royal steamers which ply between those countries.

Lord Inverclyde rendered great service to the country by drawing the attention of the Government to the methods by which merchant ships could be adapted for war purposes, and by the leading part he took in connection with the defences of the Clyde when the Government took up the question of coast defence.

He took deep interest in religious and philanthropic work in Glasgow, and was President of the Clyde Industrial training-ship *Empress*, and of the Glasgow Foundry Boys' Religious Society. He died at Castle Wemyss on the 12th of February 1901. He was elected a Fellow of the Society on the 13th of November 1874.

WILLIAM LETHBRIDGE was born on the 20th of February 1825 at Tavistock. He was a schoolfellow of the Right Hon.

W. H. Smith at Tavistock Grammar School. He went to St. John's College, Cambridge, and was 9th Wrangler in 1850. He was for some time a master at Rossall and St. Paul's Schools. In 1861 he was called to the Bar and joined the firm of W. H. Smith & Son as managing partner. In 1885 he retired from active business and went to reside in his native county of Devonshire. He took an active part in the business of the county and was High Sheriff for 1893–4. For some years he was in failing health and died on 31st of March 1901.

He was elected a Fellow of the Society on the 9th of February 1855, but has not communicated any papers to the Society.

CHARLES MELDRUM was born in 1821 at Kirkmichael, in Banffshire. He was educated at Marischal College and University, Aberdeen, and was Lord Rector's Prizeman in 1844. He entered the Bombay Education Department in 1846, and two years later was appointed Professor of Mathematics at the Royal College of Mauritius. In 1851 he founded the Meteorological Society in that Colony, and was for many years its Secretary. In 1862 he was appointed Government Observer. The principal work done at the Observatory, which was situated at Port Louis, consisted in the examination and tabulation of ships' logs. As it was surrounded by hills the locality was unsuitable for a meteorological station, and in 1863, owing to Dr. Meldrum's efforts, in which he received strong support from Sir E. Sabine, the old observatory was sold preparatory to building a new one at Pamplemousses. The foundation-stone of the new observatory, the Royal Alfred Observatory, was laid in 1870 by H.R.H. the Duke of Edinburgh. It cannot be said that the new site was very happily chosen, as the ground is marshy and fever-stricken. The Royal Alfred Observatory was provided with meteorological and magnetic instruments, a 6-inch Cooke equatorial, a 3-inch transit, and a 4-inch photoheliograph. From 1880 to 1885 sun-pictures were taken regularly on a scale of 4 inches, and from 1885 to the present time on the enlarged scale of 8 inches to the Sun's diameter.

Dr. Meldrum was more interested in meteorology than astronomy, and his principal work was in connection with the law of storms in the Indian Ocean. He discovered that the diurnal barometric variation was very regular, and that a slight deviation indicated strong disturbance at a more or less great distance. His knowledge of the prevailing winds, &c., enabled him to advise vessels proceeding from Mauritius where cyclones would be met.

The British Association Reports for 1874 and 1876 contain papers in which he tabulated the number of cyclones in the years 1856 to 1875, their duration, the distances they travelled, and the areas over which the wind blew with the force of a strong gale. He compared these with Wolf's relative sun-spot numbers, and

concluded that cyclones were fewest and least severe at a Sun-spot minimum and the converse at a maximum. He also tabulated the rainfall in different years at a large number of stations distributed over the Earth, and concluded that the total amount of rain which fell on the Earth was above the average at times of sun-spot maxima and below at minima. Neither of these conclusions has as yet been sufficiently confirmed to be beyond doubt.

Dr. Meldrum was elected a Fellow of the Society on the 11th of March 1870. He communicated to the Society in 1873 a paper on "Star Showers seen at Mauritius."

The degree of LL.D. was conferred on him by the University of Aberdeen in 1876, and in the same year he became a Fellow of the Royal Society. He was made C.M.G. in 1886, and served as a member of the Council of Government of Mauritius from 1886 to 1896. After his retirement in 1896 he lived in Edinburgh, where he died on the 28th of August 1901.

Sir Cuthbert Peek, the only child of Sir William Henry Peek, the first Baronet, was born on the 30th of January 1855, and succeeded to the baronetcy on the death of his father in 1898. He was educated at Eton and Pembroke College, Cambridge. After leaving Cambridge he went through a course of instruction in astronomy and surveying, and put his knowledge into practice in two journeys across the unfrequented parts of Iceland, taking regular observations of the latitude, longitude, and dip of the needle. On his return to England he established a small observatory with a 3-inch equatorial in his father's grounds. In 1882 he accompanied the British expedition to Australia to observe the transit of *Venus*, the party consisting of Captain Morris, R.E. (in charge of the expedition), Lieut. Darwin, R.E., and an assistant. Mr. Peek took with him a 6·4-inch equatorial and a portable observing hut. The expedition arrived at Brisbane on the 27th of October, and a few days later left for Jimbour, a well-chosen station, with an uninterrupted view of the horizon in all directions. The six weeks preceding the transit of *Venus* were occupied with observations of double stars, nebulæ, and clusters, and especially of the nebula surrounding η *Argus*, on which Mr. Peek published an interesting memoir after his return to England in August 1883. On the 7th of December, the morning of the transit of *Venus*, the sky was completely overcast, although there had been only two cloudy nights in the previous six weeks. In 1884 Mr. Peek built the Rousdon Observatory and furnished it with a 6·4-inch Merz refractor equatorially mounted, a small transit instrument, and a sidereal clock. From this date he carried on a continuous series of observations of variable stars of long period, and reports of his observations will be found each year since 1887 in the February number of the *Monthly Notices*. When Mr. Peek's observations began the difficulties of

observing long-period variables were considerable, as the observers had to determine the magnitudes of the comparison stars. These difficulties were removed in 1890 by the publication of charts and catalogues of comparison stars for variables by the Harvard College Observatory. Observations made before the 31st of December 1890 were corrected to the Harvard data, and since then the Harvard photometric magnitudes of the comparison stars have been used. Argelander's method of observing was adopted, and each observation of a variable was made by comparison with five stars of known magnitude in the same field. To the end of 1900 6,809 observations had been made and 267 maxima and 227 minima had been determined. Papers showing the light changes of ten variables have been published, and the whole of the observations made at the Rousdon Observatory, which are of great value, will appear in a volume of the *Memoirs* of the Society. Meteorological observations were also carried on, and weekly and monthly weather reports were issued from the Rousdon Observatory.

Sir Cuthbert Peek was elected a Fellow of the Society on the 11th of January 1884.

In 1884 he married the Hon. Augusta Louisa Broderick, eldest daughter of Viscount Middleton, and he leaves two sons and four daughters. He died on the 8th of July 1901.

Basil Woodd Smith was born in London on the 9th of March 1831. He was intended by his father for the Stock Exchange, but finding the work entirely uncongenial he soon abandoned it. Placed in circumstances which permitted him to give his time and counsel where they were needed, he was able to assist a number of good causes. He lived at Hampstead, and was chairman of the bench of magistrates. He assisted the local philanthropic institutions, and was for many years chairman of the Orphan Working Schools. He was a man of strong religious views, and was largely occupied in the work of the Bible Society, attending the committee meetings with great regularity for a long period. He also took great interest in Palestine exploration, and generally in all questions of Biblical archæology.

Although a good classical scholar, his interests were scientific rather than literary. He was for many years on the board of managers of the Royal Institution, and attended the lectures with great regularity. He frequently observed with a telescope he had erected on the roof of his house, and was always ready to show it to visitors and answer the questions they put to him. He was elected a Fellow of the Society on the 10th May 1861, and till recently was a regular attendant at the meetings.

Mr. Woodd Smith was twice married, and leaves eight children.

Henry Augustus Rowland, the son of the Rev. H. A. Rowland, D.D., was born at Honesdale, Pennsylvania, on the

27th of November 1848. He studied engineering at the Rensselaer Polytechnic Institute at Troy, and received the degree of Civil Engineer (C.E.) in 1870. For a short time he was a railway engineer. In 1871–2 he was science teacher at Wooster College, and from 1872–5 was assistant professor at Troy. On the 3rd of April 1876 he was appointed Professor of Physics and Director of the Physical Laboratory of the Johns Hopkins University of Baltimore, and for twenty-five years added lustre to his university by his own brilliant researches and by the band of workers he stimulated to devote themselves to the progress of physical science.

Professor Rowland's first important paper was on magnetic permeability. This work he sent to Clerk Maxwell in 1873, who replied that he was sorry he could not communicate it to the Royal Society, as that Society was not in session, but that he had sent it to the *Philosophical Magazine*, and would himself, as Rowland was so far away, correct the proofs. Before taking up his professorial work he studied a little time in Berlin, and in 1876 made the important discovery that a moving charge of static electricity, like a current, sets up a magnetic field. He made an excellent determination of the mechanical equivalent of heat, but with this exception his researches alternated between electric and magnetic subjects and those spectroscopic researches for which astronomy is so greatly indebted to him.

Professor Rowland's spectroscopic work began in 1882, in which year he published a "Preliminary Notice of Results accomplished in the Manufacture and the Theory of Concave Gratings for Optical Purposes." It is well known how imperfect were the tables of wave lengths before Professor Rowland's time, and how his researches required him first to perfect the concave grating, and how this forced him to make his perfect screw and unrivalled dividing engine. His process of making screws is described in an article by him in the *Encyclopædia Britannica*, and an account of the ruling of concave gratings is given in *Phil. Mag.* for 1882.

After ten years' work with many gratings of 6 inches diameter and 21½ feet radius, in the course of which thousands of solar and metallic lines were measured by himself and his assistant, Mr. Jewell, Professor Rowland published in 1893 a table of standard wave lengths extending from λ 2000 to λ 7700, and containing about 1,000 lines. The publication of Rowland's "Preliminary Table of Solar Wave Lengths" was begun in January 1895 in the *Astrophysical Journal* and finished in 1897. It extends from λ 2975 to 7330, and contains about 20,000 lines, and is by far the fullest catalogue of the solar spectrum yet attempted. The strong lines are nearly all referred to the element producing them, and in connection with this work Professor Rowland had obtained photographs of the spectra of all the known elements except gallium, and at intervals the results derived from the measures of these spectra

by him and his pupils appeared in the *Astrophysical Journal* as "Tables of the Arc Spectra of the Elements."

Professor Rowland's personal character is well described in the following extract from an eloquent address by Dr. Gilman, the President of the Johns Hopkins University: "Above his keen perceptions, his logic, his adaptation of means to ends, and his marvellous concentration I must place his love of truth. He was true in all his investigations, careful to eliminate errors, to avoid misconceptions, to shrink from hasty conclusions and inferences, to be critical of other investigations, to be accurate, exact, conscientious, to spare no pains, to shrink from no efforts, to conceal no difficulties, in order that the absolute facts might be established, as far as this can be done, by limited humanity. To him science was another word for truth—not all the truth, but that amount of truth which the limited powers of man have discovered. He was a follower of Isaac Newton, picking up from the seashore a few pebbles and discerning their lessons."

Professor Rowland was a member of many learned societies in Europe and America. He was elected an Associate of the Royal Astronomical Society on the 9th of December 1898. He died at his home in Baltimore on the 16th of April 1901. His body was cremated and the ashes buried beneath his famous ruling engine.

Truman Henry Safford was born on the 6th of January 1836, at Royalton, Vermont. In extreme youth he possessed extraordinary powers of arithmetical calculation, of which an account is given in *Chambers's Edinburgh Journal* for October 1847. These powers were not in his case intuitive, but were improved by study and practice, and at a very early age he obtained a knowledge of algebra and geometry. His father wisely decided to give him a good education, and at the age of ten he was placed under the charge of Professor Everett and Professor Peirce at Harvard College. In 1854 he graduated at Harvard, and immediately obtained employment at the Observatory. He remained at Harvard College Observatory for twelve years, and during this time published a number of Elements and Ephemerides of Comets and Minor Planets in the *Astronomical Journal*, and contributed several papers to the *Monthly Notices*. The most interesting of the latter is a determination of the orbital motion of *Sirius* from the observations of declination. In 1860 he prepared a Catalogue of the Declination of 532 Stars culminating near the Zenith of the Harvard College Observatory, for use in the survey of the Great Lakes in the determination of latitude by Talcott's method. In 1865, after the death of Professor Bond, Professor Safford was for a short time in charge of the Observatory. During this time he brought out vol. iv. of the Annals, consisting of a Catalogue of Standard Right Ascensions of Clock Stars and Close Polars. He also edited

vol. v., "Observations upon the Great Nebula of *Orion*," which was left unfinished by Professor Bond.

In 1866 Professor Safford was appointed first Director of the Dearborn Observatory at Chicago, and devoted himself to observations of nebulæ with the 18-inch equatorial. In consequence of the great fire of 1871, the Observatory, which was supported by private munificence, could no longer be maintained, and Professor Safford from 1871–1876 was obliged to leave astronomy for geodetic work for the United States Government. In the latter year he was appointed Professor of Astronomy at Williams College, Williamstown, Massachusetts, a post which he continued to hold till his death on the 13th of June 1901. Although his professorial duties left him but little time for research, his interest in the progress of astronomy was maintained, especially in the improvement in the accuracy of right ascensions and declinations of stars both by further observation and also by discussion of existing star catalogues. He chose as his particular field the region near the North Pole, and brought out a catalogue of the right ascensions of 133 stars within 10° of the Pole, and contributed to the *Monthly Notices* several papers on the comparisons of various catalogues in this part of the sky.

Professor Safford was a devoted and painstaking astronomer, and in the course of the nearly fifty years of his astronomical career he accomplished a considerable amount of useful work. He was elected an Associate of the Society in 1866.

Christian Wilhelm Schur was born at Altona on the 15th of April 1846. He was a relative of Dr. Petersen, the Director of the Altona Observatory, from whom he derived an early inclination to astronomy. In 1863 he went to the University of Kiel and proceeded to Göttingen in 1866, where he obtained his doctor's degree for a thesis on the orbit of 70 *Ophiuchi*. From Göttingen Dr. Schur went to Berlin and assisted Dr. Auwers in the re-reduction of Bradley's Observations, and afterwards worked for some time at the Observatory with Dr. Foerster. He was next appointed an assistant at the Geodetic Institute, where he remained till 1873, when he received an invitation from Dr. Winnecke to the Observatory at Strassburg, which had been recently rebuilt. He continued as an observer at Strassburg for ten years, except that in 1874 he went to the Auckland Islands with Drs. Seeliger and Wolfram to make heliometric observations of the transit of *Venus*. While at Strassburg he made heliometric observations of *Jupiter's* satellites, and made a large number of observations of variable stars. He succeeded Winnecke as Director of the new observatory, and spent some years in getting it into order. In 1886 he became Director of the Göttingen Observatory. Here his first task was the publication of Klinkerfues' Zone Observations. When this was finished he was able to devote himself to observations with the Repsold 6-inch heliometer. He

investigated the errors of the instrument with the utmost care and executed three very laborious triangulations—*Praesepe*, *h Persei*, and χ *Persei*—work which was planned and begun, if not finished, before the advantages of photography for this class of observations was generally appreciated.

In co-operation with Dr. Gill he made extensive triangulations of the comparison stars of *Victoria*, *Iris*, and *Sappho*, and many observations of these planets at their oppositions in 1889 for the determination of the solar parallax. Under Professor Schur's direction a re-reduction of Olbers' Comet Observations was made by Dr. Stichtenoth was made in 1898, and appears as a supplement to Schilling's *Life of Olbers*.

Professor Schur died on the 1st of July 1901, at the age of fifty-five, after a long and severe illness. His whole life was spent with unremitting industry in the service of astronomy. He was elected an Associate on the 9th of December 1898.

Proceedings of Observatories.

The following reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

Transit Circle.—During the year 1901, 11,416 observations of transits and 10,048 of zenith distances have been obtained. The total number of stars observed is about 5,000, of which 1,400 are within 10° of the pole. Half the ten years allotted to the observations for the new Star Catalogue, which will contain about 11,500 stars, are now elapsed, and it is satisfactory to be able to report that rather more than half of the work has been done, about 26,000 observations of the 10,000 zone stars having been obtained. The Sun has been observed 190 times with the transit-circle, its horizontal diameter 160 times, and its vertical diameter 180 times. The Moon has been observed 122 times in R.A. and N.P.D.: the mean error in R.A. of Hansen's Lunar Tables with Newcomb's corrections is $-0^s.141$. The errors since 1883, when Newcomb's corrections were introduced into the *Nautical Almanac*, are as follows:—1883–1893, $+0^s.043$; 1894–1896, $-0^s.057$; 1897–1901, $-0^s.137$.

The R−D discordance shows an increase on values found in 1899 and 1900, the correction to the D observation being—

$+0''.08 + 0''.22$ sin Z.D. in 1899,
$+0''.09 + 0''.32$ sin Z.D. in 1900,
$+0''.06 + 0''.44$ sin Z.D. in 1901.

Good progress has been made in the re-reduction of Groombridge's observations. The years 1806–1810 are completed, and 1811 is in hand. It is hoped that the re-determination of the mean R.A. and N.P.D. for the remaining years will be finished by the end of this year. Most of the stars in Groombridge's Catalogue which are found in Newcomb's Fundamental Catalogue were observed in the period 1806–1810 by Groombridge, and these stars have been used to determine indirectly the division errors, the accordance of the results from stars north of the

zenith with those south of the zenith in the reversed position of the instrument furnishing a satisfactory check on the values. The re-reduced places from Groombridge's observations of the stars in the *Berliner Jahrbuch* which were observed in the years 1806 to 1810 have been sent to Dr. Auwers at his request for use in the preparation of his Fundamental Catalogue.

The Altazimuth.—As much inconvenience has been occasioned through the breaking of the spider lines, which have an unnecessarily long span, the micrometer slides have been altered so as to reduce the span from 1·5 inch to 0·8 inch in R.A. and 0·6 inch in N.P.D. The instrument was out of use from Sept. 6 to Oct. 21, while this alteration was being made. In the meridian the altazimuth has been used as a reversible transit circle in all four positions. During the year 2,271 meridian observations of the Sun, Moon, planets, and stars in R.A., and 2,121 in N.P.D. have been made. The nadir has been observed 593 times, 124 reflexion and direct observations of stars have been made, and 10 determinations of flexure have been obtained. The Moon has been observed 26 times on the meridian. Out of the meridian 107 azimuths and zenith distances of stars and 12 of the Moon have been obtained. New determinations for division error of the circles have been made for every 15° by the one-circle, and for every 5° and 1° by the two-circle method, and the previous determinations have been collected and combined with these, and definitive corrections for division error adopted for reduction of the circle observations. The observation of *Eros* comparison stars has been continued, and at present, out of the 319 stars in M. Loewy's first list, 144 have been observed three times, 52 twice, and 70 once; while of the 352 stars in the second list, 86 have been observed three times, 49 twice, and 61 once. Observations of reference stars for Dr. Gill in connection with heliometer observations of the major planets have also been continued. The printing of the observations for 1899 and 1900 has been begun. These observations will be published in the Greenwich volume for 1900.

Suitable computing forms for the reduction of the extra meridian observations have been arranged and some subsidiary tables formed to facilitate the reductions.

Equatorials.—Occultations of 16 stars by the Moon have been observed by one or more observers during the year. These observations are printed in *Monthly Notices*, vol. lxii. 4.

28-inch Refractor.—Measures of distance and position-angle of 406 double stars have been made during the year, each star being observed on the average on 2½ nights. Of the 406 stars—

120 were under 0″·5 apart,

104 were between 0″·5 and 1″·0,

97 were between 1″·0 and 2″·0.

The remaining 85 are generally third companions of close pairs or difficult on account of the difference of magnitude.

All close and rapid binaries are kept under constant observation as well as all the difficult stars observable in this latitude, for which a large telescope is required. The following list gives some of the stars measured during the year :—

Star.	Mags.	Dist.	Star.	Mags.	Dist.
		"			"
β 1266	7·2 , 7·5	0·1	42 Comæ	5·5 , 5·9	0·3
β 524	6·0 , 7·0	0·2	γ^2 Androm.	5·0 , 6·2	0·3
β 525	7·0 , 7·0	0·2	Σ 234	7·0 , 7·4	0·3
Σ 2367	7·0 , 7·5	0·2	OΣ 225	5·2 , 11·2	0·8
ε Hydræ A.B.	3·5 , 6·0	0·2	Aldebaran	1 , 14	31·4
ζ Bootis	3·5 , 3·9	0·2	β 733	6·0 , 11·0	0·7

In addition good series of observations have been obtained of—

Star.	Mags.	Dist.	Star.	Mags.	Dist.
		"			"
κ Pegasi	3·9 , 5·0	0·1	ζ Herculis	3·0 , 6·5	0·9
β 883	7·0 , 7·0	0·1	70 Ophiuchi	4·1 , 6·1	1·5
δ Equulei	4·5 , 5·0	0·1			

The observations of *Capella* as a double star have been continued at every favourable opportunity during the year, and a certain number of measures have been secured, but the weather generally has not been sufficiently favourable for observations of this and other very difficult objects, especially in the latter half of the year.

Thompson Equatorial.—With the 26-inch refractor 100 photographs of *Eros* were obtained on 41 nights. A few photographs of the satellites of *Jupiter*, *Uranus*, and *Saturn* have been obtained, but the low declinations of these planets prevented any long series from being obtained. Since 1902 January 1 some good photographs of *Neptune* and its satellite have been obtained. With the 30-inch reflector 14 photographs have been taken for the nebulosity round *Nova Persei*. Photographs taken on December 4 (exp. $3^h\ 45^m$) and on December 9 (exp. $4^h\ 34^m$) show a trace of the nebula. It is shown more clearly on photographs taken December 10 (exp. 6^h), December 16 (exp. $4^h\ 48^m$), and December 18 (exp. $5^h\ 30^m$). These photographs are not entirely satisfactory, as the images have become displaced during the long exposure. The spectroscope was in use from March (when the mirror of the reflector was resilvered) to November, and 76 photographs of spectra of the brighter stars have been obtained. Some of these have been measured and are quite satisfactory, but in others displacements have been found in the

comparison spectra taken at the beginning and end of the exposure in different positions of the instrument. With a view to remedying this, the collimators and camera have been more firmly clamped and all parts examined to guard against possibility of shift. The spectroscopic observations were temporarily discontinued at the end of November, the reflector being in use for photographing the nebulosity round the *Nova*.

Astrographic Equatorial.—566 plates have been taken during the year on 139 nights. Of these, 56 have been rejected—viz. 12 because the exposure was interrupted by cloud or the plate did not come up to the standard in showing faint stars, 15 on account of fault of guiding or setting, 18 owing to photographic, and 11 for miscellaneous defects. Of the 510 successful plates, 128 were of *Eros*; 153 of *Nova Persei* and field, and 100 of the *Nova* and neighbouring stars of approximately the same magnitude; 87 for the chart, 36 for the catalogue and 6 for adjustment of the equatorial. The number of successful fields taken during the year is 82 for the chart and 34 for the catalogue. These photographs have been taken to replace some of the poorer photographs already taken. Successful photographs of more than 1,100 fields out of the 1,149 required are on the shelves. During the year 1901 positives on glass of 144 chart plates were made, which brings the total number to 1,254, of which 150 are duplicates.

During the year 1901, 112 plates were measured, both in direct and reversed positions of the plate, by two measurers, who measured the 6^m and 3^m images respectively. The measurement is now completed for the Greenwich zones from Dec. $+64°$ to Dec. $+76°$, and to Dec. $+77°$, as far as 20^h, making a total of 800 plates out of 1,149, or 1,545 square degrees out of 2,088.

The measures of 210 plates have been printed during the year. All the measures between Dec. $+64°$ and Dec. $+71°$ are now in type, corresponding to 478 plates covering 964 square degrees. The number of stars measured in this area is 68,922, or rather more than 71 per square degree.

The number of stars shown with 40^m exposure has been counted on 162 chart plates during the year. The counting up to the present time has been completed for the area from Dec. $+65°$ to Dec. $+69°$, and to Dec. $+70°$ as far as 6^h, or for about 320 plates, covering 600 square degrees.

The following table, in continuation of one given last year, gives the number of stars in Zones 67°, 68°, and 69° from 0^h to 6^h, obtained with exposures of 40^m, 6^m and 3^m, and 20^s, compared with the numbers given in the B.D., and the number given in that work down to $9^m{\cdot}0$. The first line for each zone gives the total number of stars shown, and the second line the number of stars shown twice—*i.e.* on each of the overlapping series of plates. The totals refer to all the plates counted up to the present time, Zones 65° to 69°.

Zone.	No. of Sq. Degrees.	Number in B.D. $9^m{\cdot}0$ and brighter.	Number in B.D. Total number.	Number shown on Photographs. Exposure 20^s.	Exposure 3^m and 6^m.	Exposure 40^m.
67°	138	624	1,577	1,849	9,587	44,489
				1,201	7,236	39,188
68°	132	529	1,470	2,103	9,939	45,553
				1,277	8,006	40,947
69°	32	148	364	650	2,763	15,272
($0^h{\cdot}0^m - 6^h{\cdot}0^m$)				346	2,250	13,133
Totals 65°–69°	595	2,695	7,160	9,233 5,591	41,033 31,814	197,727 171,300
Number per Square Degree		4·5	12·0	15·5 9·4	69·0 53·5	332·3 287·9

The ratios of these numbers to the number of stars given in the B.D., *i.e.* to column 4 of the above table, are—

Zone.	$9^m{\cdot}0$ and brighter.	Total No. in B.D.	Exp. 20^s.	Exp. 3^m and 6^m.	Exp. 40^m.
67°	·396	1	1·171	6·08	28·2
			0·762	4·59	24 8
68°	·360	1	1·431	6·76	31·0
			0·869	5·45	27·9
69°	·407	1	1·786	7·59	42·0
($0^h - 6^h$)			0·951	6·18	36·1
Means	0·376	1	1·290	5·73	27·6
65°–69°			0·781	4·44	23·9

Photoheliograph.—Photographs of the Sun have been obtained on 163 days; those on 43 days were taken with the Thompson photoheliograph of 9 inches aperture, and those on the remaining 120 days—viz. between February 15 and September 19, whilst the Thompson instrument was dismounted for use in the eclipse expedition of 1901 May 18—with the Dallmeyer photoheliograph of 4 inches aperture. Of the photographs taken, 339 have been selected for preservation, including 15 with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Photographs have also been received from India up to 1901 December 4, and from Mauritius up to 1901 September 11, the year ending on the former date being represented on 359 days out of the 365 by a photograph from one or other of the three observatories. The measures and reductions for 1900 have been completed and the results wholly passed for press. The Greenwich photographs for 1901 have also been completely measured. The measures and reductions for the photographs from India are complete up to 1901 October 12, and for those from Mauritius as far as received. There can be little doubt that the minimum of the Sun-spot cycle has occurred

during the past year, the solar activity, as shown in the numbers and areas of Sun-spots, having been remarkably small. The mean daily spotted area of the Sun, expressed as usual in millionths of the visible hemisphere, had fallen from 1464 for 1893, the year of maximum, to 111 in 1899 and 75 in 1900, and a preliminary estimate for 1901 places the figure for that year as under 30. This is much below the figure for 1889, the year of minimum in the preceding cycle, which was 78, and is practically the same as that in the year of minimum in the cycle before, 1878, when the area was 24.

M. Loewy came to Greenwich in June and discussed with the Astronomer Royal the details for the redetermination of the Paris-Greenwich longitude referred to in the last Report. It was arranged that the operations should be carried out in the spring and autumn of 1902. The four observers (two French and two English) will use transit instruments of identical form, the four which were used by the British observers in the Transit of *Venus* expedition of 1874. Two of these, D and E, were sent to Paris in October, and M. Loewy reports that he finds them satisfactory. Trial observations with B and C are being made at Greenwich.

Mr. Dyson and Mr. Maunder went out on the part of the Royal Observatory to Sumatra and Mauritius to observe the eclipse of the Sun on 1901 May 18, and secured a valuable series of photographs. Preliminary accounts of their observations were read at joint meetings of the Royal and Royal Astronomical Societies on October 31, and are printed in the *Proceedings of the Royal Society*, vol. lxix., and also as an appendix to vol. lxii. of the *Monthly Notices*.

The printing of the volume of *Greenwich Observations for* 1899 is completed, and a specimen copy has been received. The volume for 1900 is printed as far as the end of the Annual Star Catalogue. The heliographic results are also printed. It is hoped that a first volume of astrographic measures, embracing the zones from declination 64° to declination 72° (about one-half of the part undertaken), may be published by the end of 1902.

The re-arrangement of the library and preparation of card catalogues has been continued, and is within a short distance of completion.

Royal Observatory, Cape of Good Hope.

The 24-inch object-glass of the McClean telescope, which had been sent to Sir Howard Grubb for correction in 1899 October 31 was received in 1901 February 16. After exhaustive tests it was found to be somewhat improved as to chromatic correction, and the images towards the edges of the photographic field free from coma; but the minimum focus remains still on the less refrangible side of Hγ, and not on the more refrangible side as was desired. The object-glass has been accepted.

This completion of Mr. McClean's munificent gift was marked by the uncovering of the Inscription Stone by His Excellency the Governor (the Hon. Sir Walter Hely-Hutchinson) on September 19.* The stone bears the inscription :—

1897. THE VICTORIA TELESCOPE.
THE GIFT OF FRANK MCCLEAN,
OF RUSTHALL, KENT.
DAVID GILL, H.M. ASTRONOMER.

(This stone was cut during Mr. McClean's visit to the Cape in 1896, when there was every expectation that the instrument would be completed in the year of Queen Victoria's Jubilee.)

His Excellency stated that it had been the desire of H.R.H. the Duke of Cornwall and York to perform that ceremony on the occasion of his recent visit, but owing to the great number of public engagements which had been pressed upon His Royal Highness it had fallen to his (the Governor's) part to do so.

The iron bed-plate of the new transit-circle reached the Observatory in March, the piers and remainder of the instrument, except the collimators, in April.

No difficulty was experienced in erection and adjustment, but a great deal of time was given to experimental work in connection with insulating the piers from heat and in improving the methods for illuminating the microscopes, &c.

The instrument is uncovered, for observing, by rolling back the two halves of the steel Observatory. An admirably working plan has been carried out for opening and closing the Observatory by an electro-motor, instead of the hand motion originally supplied; the latter involved more labour than it was desirable to impose on an observer about to undertake delicate observations.

The most serious difficulty connected with the erection of the transit circle was found in the geological conditions of the site. H.M. Astronomer was desirous that, besides the ordinary collimators, there should be meridian marks in the foci of lenses of about 300 feet focus, both to north and south of the instrument. To insure the necessary stability it seemed requisite that the lenses and marks should rest on foundations built upon the solid bed-rock. When excavations had been made to north and south of the instrument for foundations of the collimator piers, it was found, at the depth of 12 feet, that nothing better than weathered rock could be found—a foundation amply sufficient for any ordinary building, but useless for that of a meridian pillar.

Accordingly a rock-boring apparatus was erected successively over the four required sites, and the bores were continued at

* The writer regrets a mistake which occurs in his speech made on that occasion, viz., the statement that Huggins undertook researches on the motion of stars in the line of sight at Clerk Maxwell's suggestion. It is now clear that that work had been begun without any previous consultation with Clerk Maxwell.

each site until the cores brought up by the diamond drill showed that the unweathered rock of the Malmesbury beds, free from crack or fissure of any kind, had been reached. The corresponding depths were :—

South meridian mark, 24½ feet ; south collimator pier, 30½ feet.
North meridian mark, 16½ feet ; north collimator pier, 34 feet.

As piers of such height could not be relied upon for permanency, H.M. Astronomer devised a plan by which the optical centres of the two long focus lenses and the centres of the two meridian marks could be rapidly and accurately adjusted, at any moment, vertically over the corresponding optical centres of lenses attached to the bed-rock below. Thus all azimuths could be referred to bearings defined by points attached to the solid rock.

The Admiralty having sanctioned the necessary cost, the work of sinking the shafts has been begun. Having regard to the depth below the surface of the ground and the age, thickness, extent, and uniformity of the quartzose Malmesbury beds, the proposed system of meridian marks will probably prove to be the most stable of any yet erected. When the work has been completed and the results tested an account of the method will be communicated to the Society.

The errors of fifteen out of the sixteen microscopes belonging to the instrument have been thoroughly investigated and the corresponding corrections computed.

Some experiments still in progress with regard to illumination of the circle of microscopes have to be completed before investigation of the division errors is undertaken.

The sinking of the water-tight shafts for giving access to the underground meridian marks and the erection of the collimators, long focus lenses, and overground marks will occupy at least six months, during which time it will probably be possible to complete the investigation of the errors of division of the circle and the pivot errors.

The annual results of meridian observations, made under the direction of Mr. Stone, 1878–79, have been printed, thus completing the issue of results of all the work done under his direction.

The printed copies of annual results, 1896 and 1897, were by inadvertence sent to the Cape, whence their distribution by post would have been unduly costly. In obedience to Admiralty orders they were returned to Greenwich for distribution in the regular way.

The annual results, 1898 and 1899, completing the meridian observations of the astrographic catalogue-plate standard stars for the zones −40° to −52°, have also been printed. This volume was also by inadvertence sent to the Cape, and has since been returned to Greenwich for distribution along with the companion volume 1896–7.

The catalogue of 8560 stars for 1900, derived from the above-mentioned observations, is now complete in MS., except the derivation of the proper motions. The preparation of the catalogue has involved applications of corrections in R.A. depending on magnitude to the separate observations of each observer, and the formation and application of systematic corrections to each zone, both in R.A. and declination, in the manner described in the introduction to the annual volumes in question. These corrections have produced a very marked improvement in the agreement of the separate results.

The Cape Catalogue for 1900, as thus formed, has been compared with Gould's Zones, the Cordoba General Catalogue, the Cape Catalogues for 1840, '50, '60, '65, '80, '85, '90, the Melbourne Catalogues for 1870 and '80, and is in course of comparison with Downing's new edition of Taylor's Madras Catalogue. The whole catalogue, with the resulting proper motions, will probably be ready for press before the end of the current year. The observations of clock, azimuth, and miscellaneous stars observed 1896–99 have been reduced to 1900 and will form a small supplementary catalogue.

The day numbers for 1903 (corresponding to Finlay's star-correction tables) were distributed along with last year's report; those for 1904 are in the hands of the printer.

The occultations observed between 1881–1895, both inclusive, have been reduced and compared with Hansen's tables. The MS. is in the hands of the printer and will form Part 3 of Vol. II. of the *Annals of the Cape Observatory*.

The general work of the transit circle has been confined to observations of stars of the new working list (see Report, February 1900). The observations made with the transit circle have been :—

Number of transits		6872
Determinations of Z.D.		6248
,,	collimation	92
,,	level	320
,,	azimuth	356
,,	run	307
,,	nadir	306
,,	flexure	19

The reductions of the meridian observations to apparent place are complete in R.A. to November 30 and in N.P.D. to November 21. The corrections to mean place are complete for 1900 and for about one-third of 1901.

Reductions to mean place have also been computed for the Dublin meridian observations of zodiacal stars.

Observations of 97 separate phenomena of occultations of stars by the Moon were obtained as follows :—

	D.B.	R.B.	D.D.	R.D.	Total.
Phenomena predicted by N.A. Office	2	1	19	13	35
Other occultations	—	—	60	2	62
					97

Of these occultations 13 stars were observed by 2 observers.

" " 3 " " " 4 "

Encke's Comet was looked for on three nights but not seen. The observations of Giacobini's Comet, secured in 1900 December, were published in the *Ast. Nach.* 3741.

Some photographs and rough "circle places" of the Great Comet of 1901 are published in the *Monthly Notices*, lxi. p. 508.

Additional observations on one night with the 18-inch, and on twenty-nine nights with the 7-inch equatorial are published (*Ast. Nach.* 3733).

The weather during 1901 has been exceptionally unfavourable. During the month of January the rainfall amounted to 5 inches, whilst the average rainfall for the same month is 0·75 inch; the greatest rainfall ever previously recorded is 2·5 inches. The general character of the definition throughout the year was much worse than usual.

With the 18-inch visual telescope *α Centauri* has been measured as a double star on six days by Gill and twenty-seven days by Innes.

Mr. Innes has besides made 342 complete sets of measures (distance and position angle) of 224 different pairs of double stars, and has detected 36 previously unrecorded double stars during the year, viz. :—

With the 18-inch 13 pairs, of which 8 are under 1″ distance.

" 7-inch 18 pairs.

Three previously unrecorded double stars have also been detected by Mr. Pett with the transit circle, and two by Mr. Woodgate in examining the catalogue plates.

The most interesting of the new pairs are :—

	Distance.	
	″	
τ_2 *Lupi*	0·3	
h 4625, chief star	0·3	
U.A. 13½ *Horologii*	0·25	
φ Argûs	20	faint comes

Variable stars requiring observations for determination of their elements were observed by Mr. Innes throughout the year. In course of the observations several new variables have been discovered. Particulars in advance of publication have been sent to Professor Müller, at Potsdam, for incorporation in the new A.G. Catalogue of variable stars.

These investigations will form part of "A Revision of the Cape Photographic Durchmusterung" (*Cape Annals*, vol. ix.), of which the following parts are ready for press :—

1. Revision of Kapteyn's lists. (In hands of the printer.)
2. Examination of stars suspected of variability.
3. Observations of proved variables.
4. Observations of stars marked * or ? by Kapteyn in the C.P.D.
5. List of *errata* in catalogues of southern stars.
6. List of coloured stars observed in course of the revision.

To these will be added a list of stars having considerable proper motions. This list is waiting for the results of meridian observations not yet completed.

The testing of the 24-inch object-glass was begun on February 21 and continued with varying separation of the lenses until April 18, when the object-glass was accepted.

As mentioned in last year's report to the Admiralty, the somewhat yellow colour of the three prisms of the line of sight spectroscope produced an undue absorption of light in the region between H_γ and H_δ; and Mr. McClean, with his wonted generosity, provided for a new battery of four prisms of very transparent glass giving together rather less dispersion and the same deviation as the three original prisms of very heavy glass. In consequence of a cable message from the Cambridge Instrument Company to the effect that the new prisms by Hilger were ready, the spectroscope was shipped to Cambridge on April 18—a few days before the appearance of the great comet. The spectroscope has not yet been returned to the Cape.

The 10° object-glass prism still remains undelivered by Messrs. Zeiss.

The $8\frac{1}{4}$° objective prism has been employed by Mr. Lunt in photographing faint stars having peculiar spectra, and for visual searching for star-like nebulæ.

Ninety negatives, mostly of long exposure, have been secured, and two star-like nebulæ have been found by Mr. Lunt by visual sweeping with the objective prism.

Their places are :—

	1900.		
	h m s		° ′
R.A.	10 56 28	Decl.	−64 43
	17 49 6		−21 47

Mr. Lunt has also been engaged on an elaborate investigation of the spectrum of Silicon with the new laboratory spectroscope by Hilger.

The heliometer, which has been in constant use since 1887, was dismounted in March and completely taken to pieces. Its various parts were repainted, repolished or relacquered, and some convenient changes in the way of new switches and carbon

resistances for regulation of the illumination were introduced. The work occupied three and a half months and was admirably done by Mr. Miller, the optical fitter attached to the Observatory, who had just returned from service at the front.

In consequence of these repairs the opposition of *Uranus* was lost, but the following oppositions of major planets were observed :—

	No. of Observations.
Opposition of *Mars*	48
„ *Jupiter*	22
„ *Saturn*	28

(On account of bad weather *Neptune* was not observed until early in 1902 January, but 30 observations have been secured previous to January 11.)

The triangulation of the comparison stars for *Uranus* 1897–1900 and *Saturn* 1898 has been completed by 21 observations of distance and 9 of position angle.

The triangulation of the comparison stars for *Neptune* 1897–1900 has been completed by 45 measures of distance including standards.

Forty-eight supplementary measures of distance (including standards) have been also made in connection with the triangulation of the South Polar area.

H.M. Astronomer has gratefully to acknowledge very valuable series of observations of comparison stars from the principal meridian observatories.

The Polar triangulation includes 22 stars situated within 2 degrees of the pole, and these offer 122 distances, all of which were measured from three to six times each with the heliometer. In other words, the observations afford 122 equations of condition for determination of 44 unknown coordinates. These equations have been formed and solved. The results have been forwarded to Professor Harold Jacoby as a basis for his discussion of an early Cape series of circumpolar photographs.

The details of the heliometric triangulation are in course of preparation for press.

An extension of the circumpolar triangulation has been planned extending to stars 6° from the pole, and 137 observations of distance (including standards) have been made in connection with that work.

Forty-eight heliometer observations of *α Centauri* as a double star have been made.

Mr. Bryan Cookson between June 24 and September 27 made heliometer measures on thirty-eight nights of the mutual distances and position angles of *Jupiter's* satellites on the same plan as that of Gill's observations in 1891. From 28 to 30 complete observations both in distance and position angle have been secured for each pair of satellites. A pair of standard

stars was observed at the beginning and end of each night's work.

These observations have all been completely reduced. An ephemeris based on Souillart's theory was computed, and the calculation of the tabular distances and position angles for the times of observations is just completed. The coefficients of unknown corrections to the constants of the theory are now being computed, and the complete equations of condition will soon be ready for solution.

With the astrographic telescope the following work has been accomplished :—

	No. of Plates.	No. of Exposures.	Duration of each Exposure. m m m
Triple exposure chart plates passed ...	57	171	30, 30, 30
„ „ „ rejected...	23	69	30, 30, 30
Revision Catalogue plates passed ...	200	600	6, 3, 20
Great Comet	17	...	various
Sundry	5	...	„

In addition to these, forty-six plates of long exposure (30^m to 45^m) in search for an ultra-Neptunian planet, have been taken in accordance with a request from Herr Hans E. Lau, of Copenhagen. The examination of the plates is not yet completed.

At the request of Dr. Backlund contact glass positives of the comet plates have been sent to Pulkowa.

During the year 159 catalogue plates, containing 100,203 stars, have been measured in both coordinates in each of two reversed positions of the plate ; all the standard stars have been measured by each of the two observers in both positions of the plate. When either coordinate of any star, as measured in one position of the plate, differs by $0''.6$ from the corresponding coordinate resulting from the measure in the reversed position of the plate, the observations in both positions are repeated.

The total number of plates measured is now 397, containing in all 220,238 stars, an average of 555 stars per plate.

The geodetic arc of meridian has been carried to the Zambesi. The country near the Zambesi Valley proved most difficult. The observing season is a very short one, as transport from Salisbury cannot be begun until the rains cease in March. In many places the grass is six feet in height, and the natives begin to burn it in July, when the smoke renders further observing impossible. In the past season's work progress was most seriously delayed by difficulty in procuring oxen for transport. As the result of some misunderstanding on the part of the officials at Salisbury the oxen and waggons selected for purchase by Mr. Simms in February were not secured, and apparently no other suitable animals could be found at Salisbury. Mr. Heatlie, one of the surveyors, was sent to Bulawayo to inspect

some oxen; he fell ill of typhoid fever, and the survey party was deprived of his services for the season. It was not until the end of April that transport could be organised and a start be made from Baruka. The original plan was that the reconnaissance and beaconing parties should start some weeks in advance of the observing party, but this was impossible because of delay in transport equipment; and, owing to Mr. Heatlie's illness, both the reconnaissance and beaconing fell entirely on Mr. Antrobus. Heavy clearing work had to be done in many places, and progress in reconnaissance and beaconing could not be made to keep pace with the observing. At the more northern stations first the waggons and then carts had to be abandoned and all transport be done by native carriers. As the result of these delays, two, perhaps three, of the stations south of the Zambesi will require yet to be occupied with the geodetic theodolite. In the interval between the work of the two last seasons the wires used in measuring the base near Salisbury were recompared at the Royal Observatory, the measurement of the angles from the base to the main triangulation was completed, and signals were exchanged for longitude of Salisbury, Mr. Simms's personal equation being determined at the Cape before and after the longitude observations.

The operations northwards from the Zambesi will involve an entirely new departure. Observers and supplies will have to be landed at Chinde and be brought up the Zambesi beyond Zumbo, where transport by native carriers would be organised.

The operations of the Anglo-German boundary survey are in steady progress.

The field work of the triangulation has practically been completed, and Major Laffan with Lieutenant Doering are engaged in beaconing the boundary from Reitfontein southwards to the Orange River. Meanwhile the computations of the northern part of the work are being completed, and advantage will be taken of the first favourable opportunity to beacon the remainder of the boundary, which in many places is so arid that it cannot be traversed except in seasons when there is an exceptionally abundant supply of wild melons, as no natural water supply, other than the juice of these melons, exists.

The printing of the re-reduction of Bailey's survey has been at last completed, and the volume is ready for distribution.

The meteorological observations made during 1900 have been communicated to the Cape Meteorological Commission.

Since November 1 an hourly signal has been supplied to the General Post Office at Cape Town, whence by a relay the signal is transmitted along a special line by which the station clocks on the Wynberg line are automatically regulated. The ordinary time signals throughout the colony and the regulation of chronometers for His Majesty's ships have been continued as usual.

Mr. Goatcher, formerly assistant to Mr. Newall at Cambridge, joined the Observatory staff on December 17.

Mr. Hough, chief assistant, has been absent on leave in England since September 11.

Mr. Bryan Cookson, having completed a post-graduate course of study at Cambridge, came to the observatory in 1901 March in order to study practical astronomy.

Royal Observatory, Edinburgh.

No change has been made in the arrangements for carrying on the time service for the cities of Edinburgh and Dundee, standard time being supplied as in former years from the Molyneux mean-time clock of this Observatory. During four days in June the time-gun was not fired, the gun being then under repair. On two other days in the year there was also no gun signal, owing to temporary derangement of the mechanism. On one day in November the time-ball was not raised on account of the violence of the wind. With these exceptions, the time service has worked satisfactorily.

Much time has been devoted to observation of the new star discovered in the constellation *Perseus* by Dr. T. D. Anderson, of this city, on February 21, at $14^h\ 40^m$ Greenwich mean time. The star, at the time of discovery, was of the 2·7 magnitude, and shone with a bluish white light. At $6^h\ 58^m$ G.M.T. Dr. Copeland estimated the *Nova* as 0·3 magnitude brighter than *α Tauri*, and at $8^h\ 10^m$ considered it equal to *Procyon*, which it closely resembled in colour. Most of the observations of the *Nova* are now reduced, and ready for publication. Two preliminary papers were read before the Royal Society of Edinburgh describing the results of the earlier observations of the spectrum and light fluctuations.

A note "On the Theory of Temporary Stars" has been published in *Nature*, No. 1654, July 11, and in *Astronomische Nachrichten*, No. 3730, July 18, by Dr. Halm, in which the broadening and the multiple character of the bright lines are explained by rotational motions of gaseous matter round an incandescent body.

In the summer Dr. Halm undertook a series of observations for determining the rotation of the Sun by the spectroscopic method first applied by Professor Dunér. The apparatus designed by him differs from that used by Professor Dunér in the employment of a heliometer for throwing the light from the two opposite solar limbs upon neighbouring parts of the slit. The observations hitherto obtained seem to indicate the great accuracy of the method. They confirm, so far, the results obtained by Professor Dunér with regard to the peculiar law of rotation of the Sun's photosphere. It is Dr. Halm's intention to continue the observations for several years, in order to ascertain, if possible,

any changes which the law of rotation may undergo during a cycle of solar activity. Dr. Halm has read two papers before the Royal Society of Edinburgh on subjects connected with his theoretical solar investigations, and has contributed three other papers to the *Astronomische Nachrichten.*

The reduction of the meridian observations made between 1834 and 1845 has been continued by Dr. Halm, assisted by the temporary computer, Mr. Henderson. The Catalogue for 1840 is now finally compiled, and the computations of the new values for the precessions nearly completed. Some time will still be required for the comparison of the star places with other catalogues. The new places for those stars which are contained in the *Fundamental Catalog der Astronomischen Gesellschaft* have been forwarded to Professor Auwers, of Berlin.

Throughout the year the Troughton and Simms' meridian circle has been under the charge of Mr. Clark. Observations of Sir David Gill's zodiacal stars have been continued as far as practicable, though the requirements of other pressing duties have interfered to some extent with the work, and the number of observations made is consequently much less than usual. The instrumental errors have been determined at frequent intervals, and have been found to be quite as satisfactory as in previous years. Every opportunity has also been taken of determining the corrections to the standard clock used for the time service of the Observatory and the city. In addition to the ordinary "outside air" and "attached" thermometers, an "aspiration" thermometer by Fuess has been used in all the meridian observations made during the year. This instrument has been suspended alternately at the north end and at the south end of the Transit House, and has been read as a wet and dry bulb in conjunction with the ordinary thermometers. It is confidently expected that in the reduction of the observations for refraction greater accuracy will thereby be obtained.

The Milne seismograph, erected 1900 December, has been in continuous operation throughout the year with most satisfactory results. The records up to December 31 have been forwarded to Professor Milne, Secretary to the Seismological Committee of the British Association. Within the year seismograms of fifty-six undoubted earthquakes were found on the photographic rolls. Of these, all except one had semi-amplitudes measured on the paper varying from a quarter of a millimètre to 5·5 mm. Assuming the motion of the boom to correspond to the actual tilt of the supporting pillar, these semi-amplitudes would be equivalent to tilts of the pillar out of the vertical through angles varying from 0·18 to 3·98 seconds of arc. The exception occurred on August 9, when a semi-amplitude of 8·5 mm. was shown on the photographic roll, equivalent, on the above assumption, to a tilt of 6·08 seconds out of the vertical. This was one of a series of four earthquakes, all of considerable amplitude, recorded between $9^h\ 36^m$ A.M. of August 9, and $1^h\ 6^m$ P.M. of the 10th,

during which period the instrument was in a state of disturbance for over twelve hours. Observation of the bifilar pendulums was discontinued in July, it being considered unnecessary to keep them working any longer, since the installation of the Milne seismograph had proved so satisfactory. It has been thought advisable, however, to start one bifilar pendulum afresh to be observed in conjunction with the Milne seismograph.

The meteorological observations have been carried on by the staff of the Observatory as in former years, and a monthly copy of all the readings has been supplied to the secretary of the Scottish Meteorological Society for the use of the Registrar-General for Scotland, the monthly means being published in the Registrar's Quarterly Returns. A copy of the temperature and rainfall readings for each week has also been furnished to the Registrar-General at his request. The Robinson anemometer and King's barograph have also been kept in operation without interruption, and the weekly readings of the rock thermometers at Calton Hill have been continued. A paper on the observations of these thermometers was read before the Royal Society of Edinburgh in February by Mr. Heath, and has been published in vol. xl. of the *Transactions* of the Society. The paper contains tables of the readings of the thermometers from May 1888 to December 1899, with their monthly, quarterly, and annual means, also a *résumé* of the whole series of observations since the erection of the first set of thermometers in 1837, and a deduction of the annual curves therefrom. The reduction of the Robinson anemometer curves from the date of the erection of the instrument on Blackford Hill has been completed by Mr. Clark.

The 24-inch mirror of the Grubb equatorial and one of the 18-inch siderostat mirrors were successfully re-silvered in November.

A short note on the total solar eclipse of 1900 May 28 was read before the Royal Society of Edinburgh by Mr. Heath, and is published, with reproductions of four photographs of the corona, in vol. xxiii. of the *Proceedings*.

Cambridge Observatory.

Meridian Circle.—During the year 1901 the meridian circle has been used for observation on 101 nights, and frequently during the day for observations of *Polaris* and other standard stars.

The observation of stars comprised in Sir David Gill's catalogue of 2798 zodiacal stars has been continued during the year; 2669 complete observations have been taken and 935 observations of stars for clock error. Since the commencement of the observation of these stars in 1900 July, 1040 have been taken not less than three times, and the places calculated as far as apparent right ascension and apparent declination to 1901 December, and to mean equinox at the beginning of the year to 1901 March.

Daylight observations of *Nova Persei* and comparison stars were obtained on February 25, 28, March 1, 2, 3, 5, 7, 12, 21. On March 25 *Nova* was not visible at 3 P.M. in a perfectly clear sky; cloudy days followed till April 1, when *Nova* was again visible on the meridian, the magnitude being estimated at $4\frac{1}{2}$. The resulting places were communicated to the Society in April (*Monthly Notices*, vol. lxi. p. 396).

Early in July three very faint circumpolar stars, together with a number of comparison stars, were observed for Dr. Stechert, of Hamburg. The resulting places, reduced to mean equinox at the beginning of the year, were communicated to him on August 31.

For instrumental deviation there have been made 78 observations of *Polaris* at the upper transit and 91 at the lower, and 61 observations of other close circumpolar stars. The observations of *Polaris* have also been utilised in making a fresh determination of the intervals of the wires.

The nadir point, level, and line of collimation have been regularly observed, and the constants for instrumental correction have been obtained from 312 equations.

At the request of Dr. Auwers a preliminary list of Cambridge transit observations made during the years 1847–1869 was communicated to him early in the year; corrections to the clock-star places used in the reductions have been sent from Berlin, but owing to the pressure of other work the preparation of the catalogue reduced to epoch 1855·0 is not yet in progress.

Sheepshanks Photographic Equatorial.—At the date of the last Report the work on *Eros*, which had been in progress since 1900 October 1, was nearly concluded. Extremely bad weather had prevailed throughout January, and it was decided to make an end of the series at the end of the month. In all, 596 exposures had been made on the planet, of which about 350 are fit for measurement. In the four months' work, despite the bad weather, enough material had been collected to occupy for a long time the energies available for measurement and reduction; to abstain for a while from making more photographs was therefore advisable. A temporary resumption of observation was necessitated by the appearance of *Nova Persei*, of which a number of plates for position and of series for photographic magnitude were secured. But the star soon passed beyond the hour-angles at which the telescope could reach it, and thenceforth to the end of the year observing was entirely suspended.

Much time was spent in developing a method of reduction of the *Eros* photographs by comparison with the tabular positions computed from two entirely separate heliocentric ephemerides of the Earth and of *Eros* expressed in rectangular coordinates. For the purposes of the experiment fifty exposures on two nights were measured and compared with special ephemerides very kindly computed for the purpose by Professor Millosevich. An account of the method, with the results of the preliminary

reductions, was communicated to the Society in November. Briefly it may be said that the results which the new telescope and measuring machine give are of a high order of accuracy, and that the method used seems to be so far promising as to deserve a more extended trial, which will be made.

When the *Eros* measures and reductions had got well under way it was time to resume observational work. The plane mirror has been re-silvered, the whole of the adjustments revised, and the instrument is now ready (18 Jan.) to begin work on a list of objects which may, it is hoped, have a sensible annual parallax. Only the very best nights will be given to this work; at present not much time can be spared from the solar parallax reductions.

Meteorological Observations.—The meteorological work has been continued on the same lines since 1899 July, when a change was made in the hours of recording barometer readings and temperatures. Weekly and monthly reports are communicated to the Meteorological Office. These include the records of hours of bright sunshine and of the rainfall.

The Newall Telescope, Cambridge Observatory.

The Newall telescope was used for observations on 91 nights in the course of the year 1901.

Throughout the year the instrument has been used in connection with the spectroscope. For the first two and a half months the four-prism spectroscope was employed in completing the material for the study of highly dispersed spectra of the brightest stars; it was also used in securing photographs of *Nova Persei*. Thirty photographs of the spectrum of the *Nova* were obtained between February 25 and March 10. The spectrum of *Capella* was photographed at certain epochs in its period, for which information is still needed for the better determination of the orbit. The spectrum of *α Persei* has been closely studied in continuation of observations communicated to the Society last year. The later observations (*Monthly Notices*, lxii. 124) show that neither of the periods suggested in the first communication will represent all the observations. The cause of the observed variation in velocity is not yet clear, and, in fact, the existence of it finds no support in the observations made at Potsdam and Mount Hamilton.

On March 11 the four-prism spectroscope was dismounted and taken to Sumatra for observations of the total eclipse of the Sun on May 17–18. A preliminary report on the observations made in Sumatra has been communicated to a joint meeting of the Royal Society and the Royal Astronomical Society (*Proc. Roy. Soc.*, vol. lxix. p. 209).

Arrangements had been made to fit a two-prism spectroscope to the equatorial, in place of the four-prism. The cast-iron box

for holding the prisms was fitted, and the instrument was adjusted in the latter part of March by Mr. A. W. Goatcher, and was steadily used throughout the rest of the year in the study of spectra of special faint stars—the *Nova Persei* included, up to November 2—and of planetary nebulæ.

A new annex has been added on the north side of the dome during the summer. It will be used as a laboratory for experimental work, which has been hitherto carried on under considerable difficulties arising from lack of space. The increased room thus obtained will, it is hoped, also give opportunities for students to take part in the work of the Observatory.

Mr. A. W. Goatcher, after nine years' work at the Observatory, was appointed to a post as computer at the Royal Observatory, Cape of Good Hope, and left Cambridge on November 23 for South Africa. Mr. H. J. Bellamy has been appointed assistant in his place.

Dunsink Observatory.

The meridian circle has been used throughout the year in the observation of the stars contained in Sir David Gill's list of 2798 zodiacal stars. The total number of these observations made since the last report is 7936. Of these 3550 observations were made of the right ascensions of the zodiacal stars and the same number of the declinations; 291 stars of the *Berliner Jahrbuch* were observed for determining the error of the Dent sidereal clock, and 268 declinations were taken for the equator point of the meridian circle; 69 determinations were made of the level error, 64 of the collimation, 62 stars of the *Berliner Jahrbuch* were observed for the error in azimuth, the nadir was determined on 64 occasions, and the error of runs on 18. The observations have been reduced to apparent place to 1901 January 31.

Photographic observations with the Roberts equatorial have been continued on the lines of former years. The South equatorial has only been used for occasional observations and by visitors on the monthly open nights.

The time service to Dublin has been continued as heretofore.

Durham Observatory.

The equipment has been completed and improved in many respects during the last year. A new sidereal clock by Kullberg has been going in a very nearly perfect manner. It is placed in the old observatory upon the stone pillar which, as in other old-fashioned places, runs through the building to support the equatorial. It is found that without special contrivance the range of temperature here is very small. In the month of

August a copy of Professor G. W. Hough's printing chronograph, made by an American firm, was delivered. Professor Hough, in the kindest manner, tested and altered the work until he could answer for its accuracy. This instrument, which works admirably, abolishes the labour of reading and transcribing the ordinary drum record, as it prints the observations plainly upon a paper tape. The accuracy of its records can be verified as often as may be thought necessary. It is used in conjunction with the Almucantar. A movable eyepiece and a wind-screen, both detached from the floating parts, have been added to the Almucantar, and in October, owing to some anomalies in its observations, the float and telescope were raised above the trough and some projecting studs removed from the bottom of the trough, as it was suspected that there was not always sufficient clearance between these and the float. When the telescope was replaced the anomalies disappeared, and since then the observations have fully come up to expectations : the instrument has been in use on all good nights in November and December. Mr. Chandler's arrangement of the reductions has been somewhat recast, and this has made it necessary to make a new computation book to facilitate reductions.

During the year Professor E. C. Pickering has kindly sent the complete MSS. of the photometric observation of *Jupiter's* satellites made at Harvard College Observatory. The number of these from 1878 to 1900 is 676, and the light curves of these have been charted, and are now ready for discussion. This work was made much easier byfacilities which Dr. Downing kindly granted to Mr. Carpenter for copying arguments and other quantities required from the *Nautical Almanac* computation books.

Meteorological observations have been continued as heretofore.

Glasgow Observatory.

Micrometric and transit observations for the determination of the constant of aberration and the motion of the pole were made with the transit circle during nine months of the year, in continuation of the work begun in 1897. Twenty-six nights were devoted to it, but only on eighteen nights more than one complete set of measurements of the faint star B.D. 89°·37, which is used as standard star, could be obtained. The reductions are up to date.

The large one-prism spectrograph, which is mounted on the 20-inch Breadalbane reflector, was used, with the exception of four nights, for photographing the spectrum of *Nova Persei*. Twenty satisfactory plates were secured, seven in March and April, and thirteen from August 1 to November 13, after which date it was not once sufficiently long clear, till the end of the year. On the first plate, taken on March 3, the spectrum extends almost as far as the D lines. Time observations were

taken on 110 nights, and the meteorological work has been carried on as in former years.

The Liverpool Observatory, Bidston.

No alteration or increase has been made in the instruments in use at this Observatory during the past year, and the purposes for which the Observatory was founded have been steadily and systematically pursued. These objects embrace the distribution of time signals, the examination of chronometers, and other philosophical apparatus, enquiries into the climate of the locality and the prosecution of such astronomical observations as the optical means permit. To take these in order it may be said there has been no failure of the time gun during the year, and the accuracy with which it has been fired is quite satisfactory. The number of chronometers, sextants, &c., deposited for test during the year is rather greater than usual; but considering the apparatus provided by the Board for this purpose, the general result is distinctly disappointing. The Richard thermograph, mentioned in the last report, and which is mounted in a Stevenson screen on the southern side of the building, has confirmed the Director's suspicions that the record of temperature in the past has generally been too high. The thermometric readings now made on the northern side seem trustworthy.

The observation of stars near the Pole, recommended by Professor Auwers, has been discontinued. Small but rapid changes in the azimuthal error, over which no sufficient control could be maintained, injured the results and would probably render them useless. The level error is not subject to the same kind of fluctuation. The equatorial has been used for comet observations, and also for double stars. Slight repairs are made to this instrument from time to time, and it is kept in a state of efficiency.

The earthquake observations, mentioned in the last report, have been continued throughout the year with a Milne seismograph for the regulation of unfelt tremors. This Observatory took part in connection with some others in an enquiry as to the effect of geological structure in influencing the record. The results have been communicated to Professor J. Milne, F.R.S., who has reported on them to the Earthquake Committee of the British Association. The attempts at observation with the bifilar pendulum have been definitely abandoned. There appeared to be no connection between the observed displacements of the two instruments, and it seemed not unlikely that an accumulation of rust on the iron rods sunk beneath the surface of the cellar, and which supported the pendulums, obscured the record and introduced irregular motions.

Radcliffe Observatory, Oxford.

During the year the work of bringing up the arrears of reduction, referred to in last year's report, has been pushed on steadily. With this object in view systematic observation with the transit circle has been discontinued during the greater part of the year, and the energy of the staff largely directed to this work, which is now in a more satisfactory condition.

All observations of right ascension have been reduced to mean place for the beginning of the year of observation as far as the end of 1898, and the reductions of the observations taken in 1899 and 1900 are in a forward condition.

The zenith distances have been completely reduced to mean place as far as 1899 February 22. The reduction of zenith distances observed from that date till the end of 1901 is well in hand.

During the year the printing of the forty-eighth volume of the Radcliffe Observations has been completed, and copies have been distributed as usual. This volume contains the meteorological results obtained at this Observatory from 1892 to 1899 inclusive. In the next volume, which, it is hoped, may be in the printers' hands before the date of the next report, will be included all the astronomical results obtained since 1892.

No further progress has been possible in the reduction of the old quadrant and transit observations made between 1774 and 1838, the Director's application for a grant for this purpose having been again postponed by the Government Grant Committee of the Royal Society. The importance of these observations seems to be generally appreciated, and the Director continues to receive from time to time letters from astronomers expressing the kindest interest in the undertaking and hopes of its successful accomplishment.

The transit circle has been employed chiefly for observing time stars. The position of *Nova Persei* was determined on seven days, viz. February 25, 28, March 1, 5, and December 11, 16, and 27. On December 9 systematic observations of working-list stars, consisting chiefly of stars between 85° and 90° N.P.D., were recommenced.

The new recording micrometer, supplied by Mr. Simms for the transit circle, has on further trial proved very satisfactory, and shown itself to be a valuable acquisition.

The Barclay equatorial telescope has been used chiefly for observations of *Nova Persei*, and a long series of observations of its brightness has been secured, extending from within three days of the time of its discovery to the end of the year. The results of these observations up to November 1 have been communicated to the Society and published in five papers in the *Monthly Notices* for March, April, May, June, and November. Some photometric measures of this star were obtained, soon after

its discovery, with a wedge photometer kindly lent by Sir Howard Grubb, and a few spectroscopic observations were made.

A special watch for *Leonids* was kept at this observatory on the night of November 14–15, the results of which have been already communicated to the Society.

Meteorological observations and automatic registrations have been maintained as usual throughout the year. Observations of underground temperature by means of platinum-resistance thermometers have been carried on uninterruptedly. The mercury-contact switch-board, for making connection between the resistance box and the several thermometers, was replaced on May 23 by one with copper contacts, which now seems to work very satisfactorily.

The mechanical parts of the large refracting telescope which, for the last three years, Sir Howard Grubb has been building for this Observatory are now complete, and the instrument is at present being dismantled, and the various parts are being packed for transport to Oxford. As reported last year, the 18-inch visual object-glass is finished, and the 24-inch photographic object-glass will probably be ready by the time the mechanical parts are erected. At Oxford progress has been made in the construction of the rising floor, the galleries, and the internal fittings of the dome. The framework on which the floor rests has been completed and hung on its counterpoises, and the work has been carried as far as it seems advisable to go before the heavier parts of the instrument have been mounted in position. The work of erecting the telescope at Oxford will be commenced forthwith.

During the year a very large expense has been incurred for repairs to the central tower, 100 feet in height, which constitutes such a striking feature of the Observatory building. The walls and ornamental projections of this tower, which was finished in 1795, had, like so many of the Oxford buildings, suffered severely from the weather, and had become in some places dangerous through the falling of pieces of stone. The greater part of the tower has been very thoroughly restored and the work is still in progress.

University Observatory, Oxford.

The main work of the year has been the measurement and reduction of plates for the Astrographic Catalogue, and two more zones have been completed, viz. zones $+28°$ and $+29°$, so that five out of the seven are now finished. The number of plates completed during the year 1901 is 151, bringing the total number up to 900 out of 1,180. It is hoped that the whole work may be finished within two more years.

In the early months of the year thirty further plates were taken of *Eros* and surrounding stars, and a large number of measures made. Acknowledgment should be made of the generous help of Mr. Frank Robbins, F.R.A.S., who has computed by

interpolation from the ephemeris of M. Millosevich 367 places of the planet at times corresponding to the exposures—a considerable volunteer undertaking.

Photographs of the region surrounding *Nova Persei* were taken on February 25 and following days, and a resulting survey of the region was communicated to the Society by Mr. Bellamy (*Monthly Notices*, vol. lxi. p. 340; see also p. 473). A similar survey of the region round the variable *RU Herculis* was made and published by him (*Monthly Notices*, lxii. p. 73).

Mr. H. C. Plummer, who was appointed second assistant at the Observatory last August, carried out an investigation of the systematic errors of measurements on photographic plates suggested by a paper recently published by M. Loewy; and found that the method of making measures in two positions of the plate differing by 180° in position angle (which originated, it is believed, at this Observatory) has an important and rather unexpected effect in the diminution of systematic error (*Monthly Notices*, vol. lxi. p. 618).

A comparison of Dr. Küstner's meridian observations with the Oxford photographic measures was made, and his (practically insensible) magnitude equation deduced, the results satisfactorily confirming his own results obtained by the "screen" method (*Monthly Notices*, vol. lxii. p. 3).

During the past year the Director carried out and published an investigation of the formulæ and tables convenient for comparing two overlapping plates (*Monthly Notices*, vol. lxi. p. 422). He also published a note on the rotation of a siderostat field (*Monthly Notices*, vol. lxi. p. 122) and another on a suggested method of conducting a terrestrial survey photographically (*Monthly Notices*, vol. lxii. p. 126). In connection with eclipse work he has made further measures of coronal brightness from photographs, but some anomalous results in the photographs of standard squares have delayed publication. He has also undertaken to edit the valuable observations of variable stars made during the last fifteen years at the Rousdon Observatory under the direction of the late Sir Cuthbert Peek, and the work of reduction (in the course of which several points of interest have arisen) is well advanced.

Mr. H. F. Mullis resigned his position as second assistant at this Observatory last July to take up an appointment at the Cape Observatory.

Temple Observatory, Rugby.

The same work as that of past years has been continued, the early portion of each evening having been given up to attempts to interest members of the school, most of whom come for the purpose of looking through a telescope only. Some have, however, attended as a class at fixed times. Mr. Lempfert and Mr.

Seabroke have continued measuring double stars, and the measures of the last five years have been prepared for publication by the Society.

Stonyhurst College Observatory.

The solar surface has been observed on 235 days, and the results are recorded by 144 drawings of spots and faculæ and 91 blank sheets. The mean spotted disc area deduced from these is 0·29,* against 0·55 of last year; and the mean daily range of the magnetic declination is 9′·1, against 9′·7 of the preceding year.

The experiments with a small prismatic camera mentioned in last year's report were complete just before the appearance of the new star in *Perseus*. A detailed description of the instrument is given in the January number of the *Monthly Notices*, in the introduction to a paper on the spectrum of *Nova Persei*, 1901. Eighty-six photographs of this spectrum have been obtained: half of these were taken between February 28 and April 26, and the other half between August 24 and December 20. Several attempts were made in May, which failed through the loss of light at the low altitude of the star.

In the intervening summer months the camera was employed on *Arcturus* and *α Cygni* for the construction of its wave-length curve, and on *β Lyræ* and *γ Cassiopeiæ* for the extension of their spectra into the shorter wave lengths.

The visual spectrum of the *Nova* was observed on 15 nights in March and April.

Markree Observatory. (*Col. E. H. Cooper's.*)

During the year this Observatory has been under the charge of Mr. F. W. Henkel, B.A., as previously, and of Mr. J. R. Armstrong in his absence.

The regular meteorological observations of a station of the second order have been continuously carried on and reduced as usual, weekly and monthly returns of barometer, temperature, sunshine, rainfall, wind and cloud, &c., having been sent to the Meteorological Office at London, weekly reports to the Registrar-General at Dublin, summaries of rainfall to Dr. Mill and Mr. Wallis at Camden Square, and to the local newspapers. Some magnetic observations have also been made. Determinations of local time with the transit circle with the instrumental corrections, &c., have been regularly made, also some observations for confirmation of the longitude of this Observatory by the method of "lunar culminations."

A few lectures were delivered in the month of February.

* The unit being $\frac{1}{1000}$ of the visible disc.

The Leonid meteors were scarcely seen here, though the weather was finer than is usually the case in November. The total rainfall for 1901 was 44·85 inches, or 3½ inches above the average.

Mr. Crossley's Observatory, Bermerside, Halifax.

There has been no change in the routine work of this Observatory since the last report. The observations of *Jupiter* and *Mars* made during the year 1901 and the measures of double stars made since 1890 have already appeared in the *Monthly Notices*.

Wolsingham Observatory. (*Rev. T. E. Espin's.*)

During the year the measurement of double stars between +30° and +60° has been continued. The total number of nights on which observations have been secured is seventy-six, the number of measures 2289, and the number of stars 349 : of these seventy-two are new, and the mean measures of the new stars have been forwarded to the *Astronomische Nachrichten*.

Sir William Huggins's Observatory, Upper Tulse Hill.

The photography of the spectra of stars and of nebulæ which has been in progress for some years has been continued during the past year.

Experiments in the laboratory in connection with the Observatory work are also in progress.

Rousdon Observatory, Lyme Regis, Devon.
(*C. Grover, Observer-in-Charge.*)

The building and equipment of this Observatory have been maintained in their usual order. Weather has been generally favourable for astronomical work, and observations have been made on 171 nights, which is about the average number. The 6·4-inch Merz equatorial has been kept at the regular observations of long-period variable stars ; 572 magnitude determinations have been made ; March and October were the two most favourable months for observation ; Argelander's method was followed, as during the previous fifteen years. At each observation the light of the variable is estimated relatively to five comparison stars in the same field of view, the mean result being assumed to be the magnitude on the date of observation. Thus during the year 1901 about 3413 observations of stellar brightness have been made. Twenty-one maxima and seventeen minima have been recorded during the year. About twenty-five variables of long period are under regular observation, and these

being mostly circumpolar, the light variations are continuously recorded.

Transits are taken as often as required for rating the sidereal clock, which has now been in use for fourteen years, with a continually increasing accuracy as a timekeeper.

Considerable attention was given to the planet *Mars*, and between February 5 and March 21 eleven drawings were made, mostly with a power of 310. Many of the well-known features of the planet, as figured by Green and Knobel in the *Memoirs* of the R.A.S., were very well seen.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

The photography of nebulæ and star clusters has been carried on during the past year on the same plan as in preceding ones. Sir W. Herschel's list of fifty-two suspected nebulous regions, which Dr. Dreyer called attention to as deserving of photographic scrutiny, have now been observed in detail, and the results will be communicated in a special paper. A list of objects photographed in the course of the year is herewith appended on the same model as those in preceding reports.

List of the principal Photographs taken in 1901.

	R.A. h m	Decl. ° ′	Expos. h m
Neb. H II. 853 Andromedæ	0 5	+32 48	1 30
Neb. *h* 12 Piscium	0 10	+11 53	1 30
Neb. M. 31 Andromedæ	0 37	+40 43	1 30 (three)
Neb. H V. 20 Ceti	0 42	−21 18	1 30
Neb. H V. 19 Andromedæ	2 16	+41 54	1 30
Region of *Nova* Persei *	3 24	+43 34	1 30 (Sept. 15) 2 0 (Oct. 9)
H's Nebulous Region No. 13 ...	4 2	+25 11	1 30
Hind's variable nebula in Taurus ...	4 16	+19 17	1 35
Cl. of the *Hyades* in Taurus	4 24	+15 26	1 0
H's Nebulous Region Nos. 14 and 15	4 24	+35 8	1 30
„ „ „ No. 16 ...	4 26	− 7 30	1 30
„ „ „ „ 17 ...	4 29	+20 50	1 30
Cl. H VIII. 8 Tauri	4 40	+18 53	1 0
H's Nebulous Region No. 18 ...	4 44	+20 50	1 30
„ „ „ Nos. 20 and 21	5 17	+25 1	1 30
„ „ „ No. 22 ...	5 29	− 6 56	1 30
„ „ „ „ 23 ...	5 30	− 2 43	1 30

* Five minutes' exposures of the *Nova* were taken on March 3, 5, 6, 12, 24, 25, and April 4. On 1902 January 5 and 12 exposures were also obtained of $2^h\ 54^m$ and 90^m respectively.

	R.A. h m	Decl. ° ′	Expos. h m
Star magnitudes near ε Orionis ...	5 35	− 1 16	0 57
H's Nebulous Region No. 26	5 37	− 6 57	1 30
„ „ „ „ 27	5 43	+ 1 8	1 30
„ „ „ „ 30	6 40	+41 16	1 30
„ „ „ „ 32	9 36	+71 13	1 30
Neb. H I. 265 Ursæ Majoris	10 12	+58 42	1 30
H's Nebulous Region No. 33	10 12	− 9 3	1 30
„ „ „ „ 34	10 22	+51 32	1 30
„ „ „ „ 35	10 41	+62 45	1 30
„ „ „ „ 36	11 4	+62 44	1 30
Neb. H I. 224 Ursæ Majoris	11 13	+58 18	1 30
Neb. H I. 201 and II. 738 Ursæ Majoris	11 42	+48 42	1 30
Neb. H I. 202 Ursæ Majoris	11 48	+48 24	1 30
Neb. H I. 207 Ursæ Majoris	12 1	+48 2	1 30
H's Nebulous Region No. 37	12 2	+30 37	1 30
„ „ „ „ 38	12 12	+30 37	1 30
Star magnitudes near η Virginis ...	12 19	− 0 7	1 0 1 30
Neb. H I. 160 Virginis	12 30	− 3 14	1 30
Nebulous Region in Coma Ber. ...	12 54	+28 29	1 30
H's Nebulous Region No. 39	13 12	+34 8	1 30
Neb. H IV. 63 Ursæ Majoris	13 26	+58 56	2 0
Neb. H I. 187 Canum Venat.	13 52	+47 43	1 30
Cl. H VI. 40 Ophiuchi	16 27	−12 50	1 30
Neb. λ 2002 Sagittarii	18 11	−19 50	1 30
Cl. M. 28 Sagittarii	18 18	−24 55	1 30
Star magnitudes near η Serpentis ...	18 20	− 2 55	0 30 1 0 1 30
Index Cat. 1287 Aquilæ	18 26	−10 52	1 30
Cl. H VI. 23 Sagittarii	18 27	−16 53	1 0
Index Cat. 1295 Aquilæ	18 49	− 8 55	1 30
N.G.C. 6764 Draconis	19 6	+50 46	1 30
Neb. H III. 743 Aquilæ	19 11	+ 6 21	1 30
Cl. H VI. 14 Vulpeculæ	19 26	+20 4	1 0
Neb. H III. 744 Aquilæ	19 37	−10 33	1 30
Index Cat. 1307 Vulpeculæ	19 38	+27 15	1 30
N.G.C. 6822 Sagittarii	19 39	−15 0	1 30
N.G.C. 6827 Vulpeculæ	19 44	+20 58	1 30
Neb. H III. 144 Cygni	19 58	+33 15	1 30

	R.A. h m	Decl. ° ′	Expos. h m
Index Cat. 1312 Sagittæ	20 12	+17 43	1 30
Index Cat. 1318 Cygni	20 19	+39 57	1 30 (two)
N.G.C. 6914 Cygni	20 21	+42 9	1 30
Index Cat. 1329 Delphini	20 39	+15 14	1 30
Index Cat. 1344 Aquarii	20 56	−13 46	1 30
Index Cat. 1360 Equulei	21 6	+ 4 39	1 30
N.G.C. 7040 Equulei	21 8	+ 8 27	1 30
Index Cat. 1369 Cygni	21 9	+47 21	1 30
Index. Cat. 1378 Cephei	21 20	+55 0	1 30
Index Cat. 1392 Cygni	21 31	+34 57	1 30
Index Cat. 1396 Cephei...	21 36	+57 0	1 30 2 0
Neb. H III. 452 Aquarii	21 49	+ 2 28	1 30
Neb. H III. 692 Aquarii	21 55	−13 41	1 30
Neb. H II. 207 Pegasi	22 3	+30 52	1 30 2 0 2 50
N.G.C. 7226 Cephei	22 7	+54 55	1 30
Index Cat. 1434 Cephei	22 7	+52 20	1 0
N.G.C. 7293 Aquarii	22 24	−21 21	1 30 2 12
Index Cat. 1453 Aquarii	22 41	−13 58	1 30
Neb. H II. 212 Pegasi	22 55	+29 10	1 30
Neb. H II. 251 Pegasi	22 55	+15 27	1 30
Neb. H II. 203 Pegasi	23 4	+17 48	1 30
Neb. H II. 706 Cassiopeiæ	23 9	+60 58	1 30
Neb. H II. 600 Andromedæ	23 17	+40 42	1 30 2 0
Neb. H II. 226 Pegasi	23 23	+21 52	1 30
Neb. H II. 208 Pegasi	23 39	+25 31	0 47 1 30
Neb. h 2266 Cassiopeiæ	23 40	+69 12	1 30
Neb. H II. 231 Pegasi	23 46	+19 33	1 30
Neb. H II. 227 Pegasi	23 59	+20 12	1 17
Neb. h 2302 Cassiopeiæ	23 59	+67 7	1 30

Mr. Saunder's Observatory, Crowthorne, Berks.

The principal work done at the telescope has been the completion of the micrometric measures of selenographic positions required for the reduction of photographic plates. In all nineteen points have been measured, each on not less than four nights,

and most of them under evening as well as under morning illumination.

An account of the use made of these measures has already been communicated to the Society, and appears on p. 41 of the November number of the *Monthly Notices*. Subsequent work upon another plate, for which Mr. Saunder is indebted to the generosity of the Director of the Paris Observatory, has shown that half of the 53 positions there given are sufficient for an accurate determination of the constants, and confirms his opinion that the preliminary difficulties of the investigation have been overcome.

On clear moonless nights the telescope has been used for comet sweeping.

Daramona Observatory.

In the early part of the year the weather was as bad as the end of the previous one, and no work could be done.

In May there was nearly a week of fine weather, and at the request of Professor G. Forbes a photographic search was commenced for his hypothetical ultra-Neptunian planet. As the field of the 24-inch reflector is so small a 6-inch portrait lens by Dallmeyer was used. This fine lens was kindly lent for the search by Sir David Salomons, Bart. A camera for it was bolted to the tube of the 24-inch reflector, and the star-images were found to be very small and sharp, except near the corners of the $8\frac{1}{2}$ inch by $6\frac{1}{2}$ inch plates which were used. The circular field was about 5° in diameter. One photograph was taken with an exposure of three hours, and two with ninety minutes each. The duplicate photographs for comparison will be taken during the coming spring.

The new pyrheliometer to be used with Callendar's electric recorder was received from the Instrument Company of Cambridge. It is mounted equatorially and driven by clock-work, and is intended to record the daily amount of solar radiation. It gives every promise of giving a valuable record.

Some further experiments were carried out in the laboratory on the effective solar temperature. The method was to balance the solar radiation with that from an absolutely "black body." The results obtained were published in the *Proceedings* of the Royal Society. The mean result comes out as 6590° C. Experiments were also made on the temperature of the crater of the electric arc, and its temperature came out as 3300° C., or just one half of that of the Sun.

Hong Kong Observatory (1900 *and* 1901).

Weather forecasts and storm warnings, and the other meteorological work, and the time-service were continued during 1900

and 1901 ; 7333 transits were observed in those two years, and it is estimated that the catalogue of R.A.'s of over 2000 southern stars will be ready for press early in 1904. About 400 micrometrical measurements of double stars, mostly southern pairs, were obtained. At Professor Pickering's request the sequences observed by Sir John Herschel at the Cape have been reduced again with photometric magnitudes from the Harvard College Observatory. An increase (above that obtained with the aid of the Uranometria Argentina) in the accuracy of the catalogue of magnitudes of stars over sixty years ago has been the result of the recalculation, and Professor Pickering intends to use Herschel's magnitudes, which are frequently as accurate as those resulting from the best modern work, in a revision of the Harvard Photometry. The recalculation of the orbits of double stars has been continued, and a new orbit of η *Cassiopeiæ* has been published in the *Astronomische Nachrichten*. *Nova Persei* was regularly observed last spring.

Kodaikanal Observatory.

During the past year the work on the buildings has made considerable progress and the main buildings have been nearly completed. Regular observations on the Sun were begun early in the year. On every day on which the Sun is visible it is examined for spots and faculæ, and the positions of any found are determined approximately by projection. Drawings are made of all important groups, and photographs are taken whenever it seems of importance.

Spectroscopic work could not be begun fully till some time later, but since September the large spectrograph has been in full working order, and a number of spectrograms has been obtained. Under instructions recently received from the Observatories Committee of the Royal Society, eye observations of the spectra of sun-spots, prominences, and the chromosphere take the first place in the work of the Observatory. Hence the early hours of the forenoon, which are the best for work on the Sun, are mainly devoted to eye observations.

Several photographs were taken of the great comet, but the conditions were unfavourable and the results not very satisfactory. Preparations were made for fully observing the annular eclipse in November, but unfortunately the day was one of the worst in the whole year, and only a few brief glimpses of the Sun were obtained through thick drifting fog.

Complete meteorological observations have been taken throughout the year, and actinometrical observations have been taken on suitable days with a Balfour Stewart actinometer and with Buchanan's solar calorimeter. Records have also been obtained without any serious break with a Milne seismograph.

Though the year here, as elsewhere throughout India, has

been a very abnormal one from the meteorological standpoint, there were 2000 hours of bright sunshine. There were, however, twenty-seven days on which there was less than half an hour, and sixty-one days on which there was less than two hours of bright sunshine. Some progress has been made with the erection of an underground building for a magnetical observatory as one of the base stations for the magnetical survey of India. Plans and specifications have been sent home for a spectroheliograph and for a plane grating spectroscope.

Melbourne Observatory.

Meridian Observations made with the 8-inch Transit Circle.

	R.A.	N.P.D.
Azimuth stars	324	130
Clock ,,	656	...
List ,,	1151	1157

The list stars were selected from the Melbourne plates of the *Astrophotographic Catalogue* to be used as standard reference stars in the reduction of these plates.

The separate results and annual catalogue for the year 1900 have been prepared. The reductions of meridian observations made in 1901 are nearly up to date. The precessions for the whole number of stars, 3100, included in the third Melbourne ten-year catalogue now in course of preparation, have been independently recomputed. The total number of standard stars for the reduction of the catalogue plates, which have been observed at least three times with the 8-inch transit circle, is 3951.

Astrophotographic Operations.—

Chart plates with triple exposure (30^m each)	68
Chart plates with single exposure (60^m each)	17
Catalogue plates (duplicate series)	98
Test plates on South Polar region	42
Test plates on Oxford typical regions	12
Test plates for adjustment of centre, focus, trails, &c....	30
Plates for comet (*a*) 1901	9
Experimental plates for investigation of magnitudes ...	41

Nine triple-exposure chart plates, two single-exposure chart plates, and three catalogue plates of the above list were rejected as defective.

The state of this work to December 31st, 1901, is as follows:—

Chart plates with triple exposure passed as satisfactory	112
Chart plates with single exposure, complete	—
Catalogue plates, first series, complete	—
Catalogue plates, second series	76

Contact prints on glass were made of the complete series of chart plates with single exposure.

The time service, weather service, terrestrial magnetism, registration of tides, rating of chronometers for the shipping, testing of meteorological and surveying instruments, and a multitude of other duties for public local requirements were carried on as usual. The reduction of arrears of magnetic records and measurement of cloud photographs have been continued by the temporary staff of computers, and are well advanced.

The Great Telescope, 8-inch equatorial, and photo-heliograph have been used only for few occasional observations and for visitors.

This comparatively narrow limit of astronomical activity at this Observatory is the unavoidable consequence of conditions which have been explained on previous occasions, and which still exist—viz. the demands made on our time by public local requirements, the clearing up of arrear records, and the grievous circumstance that no appointment has yet been made to fill the position of Chief Assistant, which has been vacant since 1895. Moreover, protracted illness of several members of the staff has very greatly interfered with the work of the year.

Sydney Observatory.

The staff of Sydney Observatory has not been changed during the year, and the work of observing the reference stars for the astrographic plates is progressing steadily. During the year the following observations have been made by Messrs. Lenehan and Raymond :—

	R.A.	N.P.D.
Clock stars	531	391 stars
Azimuth stars	171	171 „
Reference stars for plates ...	1801	1803 „
	2503	2365 „

State of Computations :—

For 1900 star constants and corrections almost completed.

„ 1901 star constants and corrections are now being checked.

„ 1901 stars observed are now being computed.

The above and previous years make 2639 stars ready as Reference stars for the astrographic photographs.

Photographic Branch.—Work has been carried on steadily. There has been little rain, but the prevailing dust and smoke

and cloud has materially hindered the work. Red Hill keeps its reputation as a good place for photography.

Star Photographs in 1901.—The photographic work has been carried on as usual; 187 chart plates were obtained, and considerable time was devoted to the comet, but a hazy sky after sunset made it impossible to get a good photograph, the photographic fog rendering the picture of the comet of no use.

Owing to the hindrances in making a new form of measuring machine considerable delay has been inevitable, but the machine at Sydney is now completed, and is ready for use in measuring star plates.

The ordinary *screw* used for small measures has been discarded, and a steel band wound up by a screw controls the micrometer slides.

The quantity measured is presented to a microscope and read off in minutes of arc, seconds and tenths of seconds, with means of estimating 0″·10. Description and photographs of the machine will be sent as soon as possible.

Measurement of the Sydney and Melbourne Plates of the Astrophotographic Catalogue. Joint Report for Sydney and Melbourne.

This work was carried on by the Measuring Bureau at the Melbourne Observatory, using the Repsold micrometer designed by Sir David Gill, and the Melbourne filar micrometers referred to in previous reports. The second Gill micrometer, which was ordered from the Repsolds as far back as May 1900, has not yet reached Melbourne, and the new machine designed by the Government Astronomer of New South Wales has not yet been placed in the hands of the bureau, in consequence of which the work has not proceeded at its full speed.

The measurements made during the year are as follows :—

One hundred and one Sydney plates, containing 71,223 stars completely measured in the direct and reverse position.

Eleven Melbourne plates, containing 4939 stars, also completely measured in the two positions.

Total number of plates measured up to December 31st, 1901:—

Sydney plates, 141 ; containing 106,919 stars.

Melbourne plates, 99 ; containing 24,494 stars.

Measures differing by less than 0″·6 in the direct and reverse position are passed as satisfactory.

The number of discrepancies greater than 0″·6 rarely exceeds 3 per cent., which is considered a fair indication of the efficiency of the measures. Arrangements are now being made for commencing the publication of the work. The method of deter-

mining photographic magnitudes will form the subject of a separate paper by the Government Astronomer for Victoria.

Perth Observatory, Western Australia.

Astrograph.—A start has at last been made in systematic astronomical work. By invitation of the International Committee this Observatory has taken zone $-32°$ to $-40°$ in connection with the Photographic Chart and Catalogue of the heavens. From a variety of causes it was not until the latter part of the year that a real commencement could be made, and even now the percentage of rejected negatives is high. This is due mainly to the difficulty of securing reliable plates. A few blemishes or a certain amount of fogginess do not necessarily cause the rejection of a Catalogue negative, but it is felt that if the chart plates are ever to be reproduced they must have clean glass free from fog or impurities in the film, and we have so far experienced great difficulty in obtaining this result. The number of plates passed so far is sixteen for Chart and twenty-four for Catalogue. The former set contains three images of each star situated at the points of an equilateral triangle, with half an hour's exposure for each. It is not proposed to take any with long single exposures.

Measurement of Plates.—No arrangements have yet been made for this, but it is hoped that the Government will shortly authorise the appointment of two ladies, who will undertake the measurements with a machine of the form designed by Professor Turner.

Transit Circle.—A working list of three stars per degree, or twelve per plate, has been prepared with the aid of the Cape Durchmusterung, and this will form the principal work for the transit observers. Each star will be observed three times, and we hope to complete a zone of two degrees per year. The work was commenced on 1901 October 6, and by the end of the year we had obtained 1072 observations of zone stars, including the necessary three determinations for 258 stars.

The level and azimuth error and nadir reading are always observed at the commencement and end of each evening's work, and the circle is read by four microscopes.

Time Service.—In addition to the zone observations 1052 clock stars were taken for clock error, and instrumental constants were determined as follows :

Level	267
Azimuth	316
Collimation	74
Nadir Point	34

The time-ball at Fremantle is dropped daily at 1 P.M. W.A.

standard time, including Sundays and holidays, and at such other hours as may be requested by the commanders of mail-boats.

There were six failures during the year—three being caused by a fault on the line, one by a heavy rainfall finding its way into the electrical machinery, one of the batteries running down, and one due to some undiscovered cause. The control of the telegraph and railway clocks worked satisfactorily throughout the year.

Meteorological.—A book on the climate of Western Australia, containing the results of past observations, and entailing a considerable amount of work, has at last been printed and is now being distributed. The preparation of this and passing it through the press has delayed the publication of the annual report for 1900, which, however, will shortly be available.

Great attention has been bestowed, as usual, on current work, and most of the stations south of the tropics were inspected by an officer from the Observatory at some time during the year.

The daily weather forecasts, which are generally looked upon by the public as the sole reason for the existence of an Observatory, have again been very successful. There are five distinct series of these, viz.: (1) and (2) general forecasts for the whole State, issued at noon and at 8 P.M. respectively; (3) and (4) special for the goldfields, issued as above; (5) special forecast for Perth, issued at 9 A.M.

The following were the percentage results for 1901 :—

	1	2	3	4
Correct	93	90	91	90
Partially correct ...	6	9	8	8
Wrong	1	1	1	2

The results of No. 5 were not tabulated, but the forecasts were almost invariably correct.

Miscellaneous.—A re-determination of the difference of the longitude between Perth and Adelaide was made in the autumn. Signals were exchanged on five nights, and the resulting longitude of the Perth Observatory is—

$$7^h \quad 43^m \quad 21^s{\cdot}97,$$

as compared with $7^h\ 43^m\ 21^s{\cdot}74$ previously obtained. A difference of this magnitude is hard to explain, although it is not large compared with results obtained in other places. At present the older value has been adopted.

A class of instruction for pupil surveyors in practical astronomy was conducted by the Government Astronomer in July and August, of which four candidates availed themselves.

A good series of observations of the Great Southern Comet (1901, I.) was obtained with the astrograph, the results of which have already appeared in the *Monthly Notices*.

New Instruments.—A Milne seismograph was mounted on September 30 in the basement of the dome building, and has been working satisfactorily.

Lovedale Private Observatory. (Dr. Alex. W. Roberts's.)

The work of this Observatory during 1901 has been the same as in previous years, viz. the observation of variable stars south of −30° declination.

One hundred stars were under regular observation during the year, the detailed work being as follows :—

	Stars.	Observations.
Algol variables	7	325
Rapid variables	2	371
Short-period variables	22	1740
Long-period variables	69	3609
Total	100	6045

Several of the Algol variables were observed with the new prismatic telescope. In this case each observation is the mean of six pointings, the field being rotated through 60° each pointing. The mean relative magnitudes thus obtained are freed from positive error.

It is hoped that these determinations will be of some service in arriving at orbital elements of the Algol stars under observation.

All short-period variables are observed twice, once direct and then with the field inverted. In this case each observation is the mean of two determinations.

The fainter stars are observed with the $3\frac{1}{4}$-inch Ross telescope, but it is a matter of regret to me that I am unable to follow faint stars below $11^{m}\cdot2$, the limit of the Ross glass. The form of the light curve of a star at its minimum phase is as important as the light curve during the star's maximum.

At the beginning of the year a preliminary paper on the elements of 95 southern variable stars was given in the *Astronomical Journal*, Nos. 491 and 492. A fuller consideration of the observations made at Lovedale, now extending over ten years, will be undertaken when a full series of measures with the new prismatic telescope has been secured.

Mr. Tebbutt's Observatory, The Peninsula, Windsor, N.S. Wales.

The following is a statement of the work at this Observatory during the year 1901 :—

Meridian Department.—

Nights on which the time was determined		106
Observations of stars with a declination not exceeding −40° ...		479
Observations of stars in high declination for azimuth		109
Separate determinations of	level error	288
	collimation error	27
	azimuth error	78

The year was throughout a dry one, and as a consequence the disturbances of the level error were small.

Extra-meridian Department.—The following micrometer comparisons were made with the equatorials:—

	Nights of Observation.	Number of Comparisons.	Number of Comparison Stars.
Venus	4	54	3
(1) Ceres	6	60	2
(11) Parthenope	9	114	5
(18) Melpomene	10	136	5
(78) Diana	4	47	2
Comet I. 1901	32	273	39

In addition to the above work twenty-eight southern double stars were measured, and a few occultations of stars by the Moon were observed. The usual meteorological observations were also taken.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1901.

Thirty-six new planets were discovered during the past year, as follows :—

Provisional Designation.	Permanent Number.	Name.	Date of Discovery, 1901.	Discoverer.	Place of Discovery.
FV	464	...	Jan. 9	Wolf	Heidelberg
FW	465	...	„ 13	„	„
FX	466	...	„ 17	„	„
FY	467	...	„ 18	„	„
FZ	468	...	„ 18	„	„
GB	469	...	Feb. 15	„	„
GC	473	...	„ 17	„	„
GD	474	...	„ 17	„	„
GE	...	...	„ 20	Carnera	„
GF	...	...	„ 22	Wolf	„
GG	...	...	„ 22	„	„
GJ	470	Kilia	Apr. 21	Carnera	„
GK	...	...	„ 24	Wolf	„
GL	...	...	May 21	Wolf, Carnera	„
GM	...	...	„ 23	Wolf	„
GN	471	...	June 7	„	„
GP	472	...	July 12	„	„
GQ	476	Hedwig	Aug. 17	„	„
GR	477	...	„ 23	„	„
GT	...	...	Sept. 19	Wolf	„
GU	478	...	„ 21	Carnera	„
GX	...	...	Oct. 11	Carnera, Kopff	„
GY	...	...	„ 11	„	„
GZ	...	...	„ 13	Kopff	„
HA	...	...	„ 13	Carnera, Kopff	„
HB	...	...	„ 16	Kopff	„
HC	...	...	Nov. 2	Wolf, Kopff	„
HD	...	...	„ 5	„	„

Provisional Designation.	Permanent Number.	Name.	Date of Discovery, 1901.	Discoverer.	Place of Discovery.
HE	...	...	Nov. 3	Kopff	Heidelberg
HF	...	...	„ 6	Wolf	„
HH	...	...	„ 12	„	„
HJ	479	...	„ 12	Carnera	„
HK	...	...	„ 16	„	„
HL	...	...	Dec. 16	Wolf	„
HM	...	...	„ 5	Kopff	„
HN	475	...	Aug. 14	Stewart	Arequipa

To these should be added the following planet, discovered in 1900, but not announced till after the last Annual Report :—

GA	...	...	1900 June 28	Keeler	Lick

The planets provisionally designated GH, GS, GW, HG proved to be identical with 449 *Hamburga*, 453, 247 *Eukrate*, 455 *Bruchsalia* respectively. FT is not identical with (220) *Stephania*, as was conjectured last year. HK may be 367 *Amicitia*. GV is 202 *Chryseis*.

Planets FT, FU, GA, GE, GF, GG, GK, GL, GM do not receive permanent numbers, not having been sufficiently observed. The announcement of the discovery of GO was cancelled as erroneous.

The following planets have been named :—

No.	Name.	No.	Name.	No.	Name.
356	Liguria.	381	Myrrha.	419	Aurelia.
358	Apollonia.	382	Dodona.	423	Diotima.
361	Bononia.	388	Charybdis.	424	Gratia.
362	Havnia.	389	Industria.	425	Cornelia.
363	Padua.	390	Alma.	432	Pythia.
364	Isara.	393	Lampetia.	435	Ella.
365	Cordoba.	397	Vienna.	436	Patricia.
367	Amicitia.	399	Persephone.	442	Eichsfeldia.
370	Modestia.	402	Chloe.	443	Photographica.
372	Palma.	403	Cyane.	446	Æternitas.
373	Melusina.	404	Arsinoe.	447	Valentine.
374	Burgundia.	405	Thia.	448	Natalie.
375	Ursula.	407	Arachne.	449	Hamburga.
376	Geometria.	408	Fama.	450	Brigitta.
377	Campania.	409	Aspasia.	451	Patientia.
378	Holmia.	415	Palatia.	454	Mathesis.
379	Huenna.	417	Suevia.	455	Bruchsalia.
380	Fiducia.	418	Alemannia.	457	Alleghenia.

The following planets have been observed at one opposition only: (99) *Dike*, (132) *Æthra*, (155) *Scylla*, (156) *Xanthippe*, (157) *Deianira*, (193) *Ambrosia*, (220) *Stephania*, (285) *Regina*, (290) *Bruna*, (293) *Brasilia*, (296) *Phaëtusa*, (309) *Fraternitas*, (310) *Margarita*, (315) *Constantia*.

From this point we omit the names and give number only: 316, 319, 320, 323, 327, 330, 341, 353, 355, 357, 359, 360, 368 383, 392, 393, 394, 395, 396, 398, 399, 400, 406, 408, 410, 411, 413, 414, 417, 421, 422, 426 to 431 (incl.), 436, 437, 438, 441, 448, 450, 452, 455. All the other planets from (1) to (456) inclusive have been observed at two or more oppositions.

We may note the rediscovery last year of the two interesting planets (361) *Bononia*, (401) *Ottilia*. The former has the greatest aphelion distance (viz. 4·74) of the whole family, while the mean motion of the latter (584″) is approximately double that of *Jupiter*.

The planet HN is interesting from its very high south declination (61½°) at discovery, also for its very large eccentricity (e=0·38) and its small perihelion distance (1·60). It was near perihelion when discovered, and will probably be altogether invisible at aphelion oppositions.

Dr. Bauschinger, Director of the Berlin Rechen-Institut, has published an interesting table of statistics of the minor planets discovered up to the end of 1900, which completes the first century of our knowledge of them. We give a summary of some of his results.

The ascending nodes show a decided tendency to cluster in the neighbourhood of the ascending node of *Jupiter's* orbit; this is in satisfactory agreement with Newcomb's theoretical results.

Of the inclinations 315 are under 10°, 133 between 10° and 20°, 29 between 20° and 30°, 1 (*Pallas*) over 30°, 107 have the eccentric angle ϕ between 0° and 5°, 195 between 5° and 10°, 132 between 10° and 15°, 27 over 15°. There seems a slight tendency for great inclination and great eccentricity to go together, but no connection between eccentricity and mean distance is indicated.

The longitudes of perihelia show a well-marked maximum near the longitude of *Jupiter's* perihelion, and an equally well-marked minimum near the longitude of his aphelion.

The question is discussed whether this could arise from some months being more favourable than others for discovery, but Dr. Bauschinger finds that the phenomenon cannot be thus accounted for and must be real. The fact, however, that September is far the most fruitful month of discoveries receives an explanation; for the rich region of perihelia souths near midnight; in addition to this the weather is usually fine, the nights dark, and the altitude of the ecliptic at midnight considerable.

Newcomb had already deduced theoretically that the perihelia should be more numerous in the neighbourhood of *Jupiter's* perihelion.

Arranging the planets in order of mean daily motion the gaps near 900″ and 600″ (that is, three times and twice *Jupiter's* mean daily motion) are very strongly marked; there are other less strongly marked gaps.

Dr. Bauschinger accordingly divides the family into three groups:

	Planets.
The *Mars* group with μ between 2015″ and 900″	108
The chief group „ „ 900 „ 600	337
The *Jupiter* group „ „ 600 „ 400	18

Then follows a discussion of the brightness and probable dimensions of the small planets. It is concluded that very few brighter than the 10th magnitude remain to be discovered, but the fainter ones show no signs of exhaustion.

The mean albedo is assumed 0·240, midway between that of *Mars* and *Mercury*; *Mars* is assumed to be of magnitude −1·79 at mean opposition, and its semidiameter to be 4″·68 at unit distance. The following equation then gives the radius ρ of a planet in kilometres:

$$\log \rho = 3{\cdot}3135 + \log [a\,(a-1)] - \tfrac{1}{5}\, m_0.$$

A table of double entry is provided, with arguments log a and m_0, enabling the radius of a planet to be at once inferred.

It goes without saying that no stress can be laid on individual diameters deduced by this method, since we know by Professor Barnard's measures on the four brightest asteroids that their albedoes vary greatly.

We give the diameters and albedoes deduced by him, for comparison with the results of Dr. Bauschinger's formula:

	Diameter in miles.		Albedo.	
	Bauschinger.	Barnard.	Bauschinger.	Barnard.
Ceres	482	477	0·240	0·195
Pallas	364	304	„	0·257
Juno	182	120	„	0·488
Vesta	518	239	„	0·825

It will be seen that Dr. Bauschinger's diameters are on the whole considerably in excess of Professor Barnard's, and probably a higher albedo than that selected by the former would have given more reliable results. The mean of Barnard's albedoes is 0·44; if we adopt this as our standard albedo we must reduce all Bauschinger's diameters in the ratio $\sqrt{\frac{6}{11}}$ or 0·7386.

The formula for the diameter of a planet in miles using this albedo would be:

$$\log (\text{diam. in miles}) = 3{\cdot}2763 + \log [a\,(a-1)] - \tfrac{1}{5}\, m_0.$$

Bauschinger's diameter for *Eros* is 32 km., or 20 miles. It would be 15 miles, using the above formula.

The volume of the 12 largest planets (Nos. 1, 2, 3, 4, 7, 9, 10, 15, 16, 22, 29, 349) forms $\frac{2}{3}$ of the volume of the whole; and since the tiny planets now discovered add so little to the volume, Dr. Bauschinger estimates that the entire family (including those still to be discovered) would form a sphere of radius 660 km., or diameter 830 miles, which would become 610 miles, using the albedo 0·44. This is $\frac{1}{13}$th of the Earth's diameter; and if we estimate the mean density as $\frac{2}{3}$ of the Earth's, the total mass would be $\frac{1}{3300}$ of the Earth's, or $\frac{1}{40}$ of the Moon's.

Such estimates are, however, apt to be fallacious, for there may be numerous planets of considerable relative mass near *Jupiter's* orbit, which are invisible owing to distance.

A. C. D. C.

The Planet Eros.

Observations of this planet for parallax were continued up till April last. There is reason to believe that active progress is being made with the measurement and reduction of the plates, but scarcely anything has yet been published.

Numerous meridian observations have been made of the reference stars, and M. Loewy has already published a preliminary catalogue, which, however, will not be definitely adopted till after the observations of the present season have been included.

The discovery of the variability of the planet in a period of $2^h\ 38^m$ was made by Herr E. von Oppolzer in February last, and confirmed by numerous observers; the range of variability seems to have been more than a magnitude. M. Ch. André considered that two consecutive waves of the variation were not exactly symmetrical, and consequently that the complete period should be taken as $5^h\ 16^m$. This result, while probable, can scarcely be considered as definitely established. There have been three theories to account for the variation :—

(1) That the planet is double, consisting of two bodies revolving almost in contact in a period of $5^h\ 16^m$. Mutual occultations take place when the plane of motion passes through the Earth.

(2) That it is shaped like a dumb-bell; the further suggestion is made that two spherical bodies may have collided and adhered together. Mutual occultations would take place as above when the Earth was in the plane of motion.

(3) That the variation is simply caused by large differences of albedo of various parts of its surface.

All of these hypotheses are open to objection, but it would seem that they exhaust the possible explanations. The fact that the large variation of light was temporary seems to favour (1) or

(2). There is evidence that the variation in 1901 January was much less than in February, and by May 8 it had sunk to zero, according to Professor Wendell, of Harvard Observatory. The Harvard photographs of former apparitions have been examined for variation in light. The range seems to have been very small at the time that the 1893–94 photographs were taken, but larger in 1896 June, when it seems to have been about 1 magnitude.

It is most desirable that accurate observations both of the position and brightness of the planet should be made at every apparition; the former in order to determine the perturbations by the Earth, which will in the course of years give a very reliable value of the solar parallax; the latter to determine the explanation of the light changes. At the next opposition the planet will be too far south for European observation; but observations will be possible next autumn, when the planet will be in perihelion, and consequently nearly as bright as at opposition. The following ephemeris is abbreviated from Harvard Circular No. 61.

Date.	R.A. h m	Decl. °	Mag. m	
1902 Sept. 27	8 42	N. 25·0	12·45	
Nov. 16	11 37	N. 2·3	12·09	perihelion
1903 Jan. 5	14 9	S. 21·7	12·07	
Feb. 24	16 30	36·1	12·11	
Apr. 15	18 5	43·1	11·79	
June 4	17 14	43·5	11·55	nearest Earth
July 24	16 21	31·1	12·41	
Sept. 12	17 17	S. 25·4	13·43	

A. C. D. C.

The Comets of 1901.

Giacobini's comet, discovered on 1900 December 20, to which reference is made in the last report, and whose orbit seemed likely to prove interesting, has unfortunately been very little observed on account of its extreme faintness. Dr. Aitken observed the comet on February 15 with the 36-inch refractor of the Lick Observatory, but this is an isolated position, measures having generally ceased a month earlier. Dr. Kreutz's short-period ellipse represented the motion of the ellipse in February, but no farther enquiry into the orbit has been made.

The Great Comet appears to have been independently seen at several places in the southern hemisphere. At Paysandu it was reported as early as April 12, and certainly through the latter end of April onwards through May the comet was a most conspicuous object as it swept through the constellations of

Pisces, *Eridanus*, and *Orion*, moving nearly parallel to the equator. At the time of the earliest observations the comet was visible only in the morning sky, but after passing perihelion on April 24, it was visible in the evening and attracted considerable attention from the brilliancy of the nucleus and the shape of the tail. The former on May 2 rivalled *Sirius* in lustre, and was distinctly elliptical in shape. The tail has been described as triple, but it is difficult to reconcile that description with the photographs and drawings that have come to hand. The main tail was seen to be divided by a distinct rift, while a quantity of cometic matter near the nucleus varied greatly in brilliancy, suggesting another tail. Major Eddie, who made a study of the comet at Naauwpoort, gives a description of what he saw on May 4, which coincides very closely with the pictures that have arrived from the Cape of Good Hope. "The head was sharply defined on its western periphery, but its following portion was somewhat fuzzy and rugged. The principal tail was sharply defined on its northern border and had a central condensation, also a dark rift, which gave it a bifurcated appearance. The lateral tail was much dimmer and broader and seemed to proceed from behind the nucleus; the cometic matter composing it appeared to be striated, and to be of even luminosity throughout."

The most northern observatory at which the comet was observed was the Lick, and the orbit rests entirely on the measures made in the southern hemisphere. Mr. Merfield, employing three normal places extending from May 6 to June 6, derived a very elongated ellipse, but he appears to prefer a parabolic motion. The perihelion distance, though small, is much greater than is the same element in the family of southern comets from 1843 to 1882, so that no connection is probable between the 1901 comet and the other brilliant visitors of which so many examples have appeared in the last few years.

The only other comet that has been under observation is that of Encke. The preparation of the ephemeris to assist its recovery was undertaken by Dr. Thonberg, of the Kronstadt Observatory, and the comet was found by Professor Wilson, of Northfield, U.S.A., on August 5, very near the predicted place. The earliest observations showed that the mean anomaly required a correction of $-4'\ 24''$, or that the time of perihelion passage was in error about six hours. The path of the comet at first through *Gemini* and *Cancer* allowed observations to be made in the northern hemisphere, but early in September the comet moved rapidly to the south, and was too near the Sun to be visible. In October the comet was south of the Sun and observations were only possible in the southern hemisphere, and details have not yet been published.

To this scanty record of cometary observation must be added the unwelcome fact that two comets have passed through perihelion without being seen. The first of these, that of

Brorsen, was looked for in vain at Arequipa, where a systematic search was maintained by means of the Bruce photographic telescope. The date of the perihelion passage of Comet 1894 I. (Denning), the other missing comet, is extremely uncertain, but short sweeping ephemerides were prepared by Dr. Neugebauer, apparently without success.

Definitive elements of several comets have appeared during the year, and in this field of heavy work we may recognise the services of Mr. C. T. Merfield, of Sydney, who, besides doing much useful work in the way of supplying orbits and ephemerides of comets while under observation, has calculated definitive elements of Comets 1898 VII. and 1899 I., both of which are hyperbolic. The orbits of several other comets have been placed in a more satisfactory position by the efforts of other computers, and it seems likely that a stimulus will be given to this class of work by the proposal of Mr. Lindemann, of Sidmouth, to give a money prize for the satisfactory determination of the orbits of many comets which have hitherto been neglected. W. E. P.

Progress of Meteoric Astronomy in 1901.

January Meteors.—Moonlight and cloudy weather prevented the *Quadrantids* being successfully observed in 1901.

April Meteors.—The shower of *Lyrids* was well seen on April 21, but on previous nights meteors were rather scarce, though the skies were clear and free from moonlight. On April 21 the hourly rate of apparition of all meteors for a single observer was about 25, of which number one-half were *Lyrids*. They were rather swift, bright meteors with streaks, and the radiant appeared to be about 5° in diameter, with centre at 270°+33°. A moderately bright *Lyrid* was well observed at Slough and Bristol on April 18, and indicated the radiant at 266°+33° on that date, thus affording a new and significant link in the evidence affirming the easterly motion of the radiant of about 1° per diem. At Bristol, during a watch extending over 5 hours on April 20 no certain *Lyrids* were noticed among a total of 29 meteors recorded, but Professor Herschel, at Slough, saw several *Lyrids* on the same night. On April 21, during a watch of 3 hours, he enumerated 18 *Lyrids*, while at Bristol 25 *Lyrids* were registered in $3\frac{1}{4}$ hours. On April 21 Mr. C. L. Brook, at Meltham, near Huddersfield, saw 40 or 50 meteors, including a number of *Lyrids*. On April 12, 17, and 22 Mr. J. C. W. Herschel, at Cambridge, observed 60 meteors, of which 40 were directed from the region of *Lyra*. The radiant appeared to be multiple, and exhibited no traces of motion. Professor A. S. Herschel, from an investigation of many of the paths recorded by different observers, concluded that they gave "two mean centre-points, at 266°+30° to 271°+30°, the latter being chiefly marked on April 21, and then very sharply defined, while the former point

ceased to be traceable after April 20 ; hence if a real motion of the time was thus indicated in the radiant point's position, it seemed to be onwards in R.A. about 5° on the four nights, April 18–21, along a parallel of declination."

July and August Meteors.—Moonlight prevented observation at the close of July and early part of August. At the middle of July the weather was tolerably clear, but meteors were rather scarce. The first *Perseids* were noticed on July 21, when the radiant point of the shower was at 23°+52°. At Bristol the nights of August 10 and 11 were fine, and 172 meteors were observed. August 12, 13, and 14 were cloudy, but an unusually long period of clear weather followed, for the 10 nights from August 15 to 24 offered excellent opportunities for tracing the *Perseid* shower through its later stages, and 220 meteors were observed by Mr. Denning. There were a few *Perseids* visible on every night of the period, and the easterly movement of the radiant was well marked. The maximum of the shower appeared to be attained on the morning of August 13, but the cloudy state of the firmament prevented fair comparisons being made. Mr. Wm. Mitchell, of Maine, U.S.A., saw 42 meteors in the hour between 10 and 11 on August 13, and Mr. R. M. Dole, at Oganquit, U.S.A., counted 79 *Perseids* in 5 hours between 8.30 and 13.30 on August 13, so that the display certainly exhibited unusual strength at a period which we regard as late for the *Perseids*. Miss Bolton, at Leeds, counted 125 *Perseids* on August 10 in $2^h\ 25^m$, while on the night of August 11 119 were noted in slightly less than 2^h, so the numbers were nearly similar on the two nights. On the whole the display was decidedly richer than that witnessed in an ordinary year, and furnished the usual proportion of large meteors, some of which were registered at several stations and their real paths ascertained. A great number of astronomers, at home and abroad, participated in the observations, but it is impossible to refer to their individual results, many of which have already been published in *Astronomische Nachrichten*, *Nature*, *Popular Astronomy*, *Journal of the B.A.A.*, *English Mechanic*, and other serials.

October Meteors.—This shower was fairly well seen at several stations, but it was not of special character. As observed at Bristol on the night of October 20, the principal radiant was at 99°+13°, as on 1900 October 23. Formerly the chief centre was at 92°+15°, and it will be important to watch the *Orionids* thoroughly during the ensuing few years to ascertain whether the stronger shower emanates from *υ Orionis* or *ξ Geminorum*. Mr. R. M. Dole, at Jamaica Plain, Mass., kept a watch on October 19 between 13^h * and $16^h\ 15^m$,* and observed 89 meteors : 55 of these were from the *Orionid* radiant, 11 from *Gemini*, 8 from *Taurus*, 3 from *Leo*, 5 from *Perseus*, and 4 from *Aries*. The

* In all cases local times are given. This description and some others relating to the *Leonids* are condensed from *Popular Astronomy*.

maximum was attained at $13^h\ 40^m$–$13^h\ 50^m$. There were some curious meteors; one from *Pegasus* lit up earth and sky like the new Moon, and curved as it died out so that it made a semicircle. Two of the meteors from *Gemini* started as lines and broadened as they shot. One, which was as bright as *Venus*, made a triangle; another ended in a burst about 1° in diameter. The *Orionids* came in shoals with a maximum every 20 minutes.

November Meteors.—The *Leonids* were not expected to appear in unusual numbers in 1901, but the shower was very generally looked for, and the weather being favourable just at the important time the results obtained were satisfactory if they were not sensational. The display was well marked, but it is certain that the maximum occurred after sunrise in England on November 15, so that the results obtained in this country are not nearly on a parallel with those coming from America. The following are a few extracts from the descriptions of the shower :—

Observer.	Date.	Time of Watch.	Duration.	Leonids.	Other Meteors
		h m h m	h m		
A. S. Herschel, Slough	Nov. 14	11 to 15¼	4¼ hrs.	6	...
	15	12½ „ 15¾	3¼ „	12	...
J. H. Bridger, Farnborough	Nov. 14	14 37 „ 16 22	1 45	18	
	15	16 55 „ 18 0	1 5	6	2
P. M. Ryves, near Exeter	Nov. 14	12 22 „ 15 0	2 10	20	26
	15	13 20 „ 17 0	2 30	51	35
H. Corder, Bridgwater	Nov. 14	... ...	1 30	37	13
C. L. Brook, Meltham	Nov. 13	15 0 to 16 30	1 30	2	8
	14	14 45 „ 18 15	2 55	59	13
	15	14 20 „ 18 15	3 10	28	11
	16	14 35 „ 17 40	2 35	13	18
E. C. Willis, Norwich	Nov. 14	13 0 „ 17 50	4 45	106	94
	15	11 45 „ 17 35	5 0	89	89
	16	12 15 „ 14 15	2 0	7	29

A watch was kept at Greenwich on November 14, 15, and 16, and between 40 and 50 *Leonids* were seen after midnight on each of the two first nights. Mr. P. M. Ryves gives the maximum as occurring on November 15, 16^h to 17^h, when there were 27 *Leonids*. Mr. W. H. Milligan, of Belfast, says that on November 14, between $15^h\ 30^m$ and 18^h, the horary rate of all meteors was 40 to 50, and that the maximum was at about 17^h. Mr. J. R. Heury, of Dublin, watching the sky on November 14, between 13^h and $15^h\ 30^m$, says the meteors of the first and second magnitudes shot steadily from the Sickle at the rate of about 12 per hour.

In America meteors were much more plentiful. At Carlton College, Northfield, Minn., one observer watched the sky on November 14 from $12^h\ 30^m$ to $17^h\ 50^m$, and during this interval of $5^h\ 20^m$ counted 621 meteors. For an hour before $15^h\ 30^m$ 124 were seen; from $15^h\ 30^m$ to $16^h\ 30^m$, 209; and from $16^h\ 30^m$ to $17^h\ 30^m$, 187. Another observer during the latter period counted 100 meteors in 27 minutes, none of which were less in brightness than a star of mag. 2. Mr. Payne estimates that four observers might possibly have counted 1600 meteors (large and small) per hour. Several brilliant fireballs were noted. Mr. Winslow Upton, of the Ladd Observatory, Providence, gives the following numbers :—

	h	m		h	m	Leonids.	Sporadic.
Nov. 14	15	0	to	15	30	34	1
	15	30	„	16	0	58	7
	16	0	„	16	30	61	7
	16	30	„	17	0	66	7
	17	0	„	17	30	60	8

There were about 2 *Leonids* per minute between $15^h\ 30^m$ and $17^h\ 30^m$.

Mr. E. L. Larkin, at Echo Mountain, Virginia, maintained a watch on the night of November 14, with the following results :—

	h	m		h	m	Meteors.
Nov. 14	12	0	to	13	0	32
	13	0	„	13	54	27
	13	54	„	14	43	Clouds
	14	43	„	15	0	19
	15	0	„	16	0	173
	16	0	„	17	0	297
	17	0	„	17	40	109

Thus between $16^h\ 0^m$ and $17^h\ 0^m$ meteors appeared at the rate of 5 per minute. The estimated brightness of about one-third of the total number seen was as under :—

	Meteors.
Twenty times brighter than *Venus*	2
Ten „ „ „	3
Five „ „ „	12
Equal to *Venus*	25
„ *Jupiter* at maximum	40
„ *Sirius*	20
„ *Rigel*	120

The streak of one meteor remained visible for 14 minutes; of another, 6 minutes. The magnitudes summarised above show that a large proportion of the visitors were brilliant, yet Mr. Winslow Upton, whose results, obtained at Ladd Observatory, have already been quoted, says that a few only of the meteors seen by him were brighter than stars of the 1st mag.

Mr. W. C. Brenke, at the Observatory of Illinois, reports that three observers there counted 433 meteors on November 14, $13^h\ 30^m$ to $17^h\ 30^m$. The maximum was between 17^h and $17^h\ 5^m$ when the rate of apparition was 288 per hour.

Mr. R. M. Dole, of Jamaica Plain, Mass., counted the following numbers :—

	h m	h m	Leonids.	Others.
Nov. 14	15 0	to 16 0	43	0
	16 0	„ 17 0	74	4
	17 0	„ 18 0	48	4

The maximum was from $16^h\ 30^m$ to 17^h. Three of the meteors were brighter than *Venus*, 2 equal to *Venus*, and 26 equal to *Jupiter*. Mr. W. P. Russell, in Illinois, on November 14, $17^h\ 36^m$ to $17^h\ 40^m$, observed 13 *Leonids*; so the rate of apparition was about 3 per minute. Mr. J. Salloms, at Dunmore, British America, on November 14, $16^h\ 30^m$ to $17^h\ 30^m$, counted 186 meteors, or 3 per minute. At $16^h\ 10^m$ a brilliant *Leonid* travelled from the Sickle to N.W., and left a streak for 20 minutes. Mr. Salloms remarks that the great majority of the meteors appeared to reach points near the horizon before being extinguished.

The display in America would appear to have been pretty rich, on the mornings of both November 15 and 16. A telegraphic despatch from Phœnix states that a shower of great brilliancy occurred on the morning of November 16. In 30 minutes one observer counted 200 meteors. At Los Angeles the fall of *Leonids* was quite marked before daylight on November 16. In the hour from 4 to 5 A.M. one observer saw 385 meteors.

December Meteors.—The *Geminids* seem to have been less active than usual. On December 10, $9^h\ 50^m$ to $10^h\ 30^m$, Mr. T. H. Astbury, at Wallingford, saw 6 meteors, including 2 *Geminids*. Later on the same night, at Bristol, about 17 meteors were recorded in two hours, but there were only 1 or 2 *Geminids*.

Mr. W. E. Besley, of London, watched the sky on December 10 between $11^h\ 12^m$ and $13^h\ 22^m$ and recorded 21 meteors, of which about 9 were *Geminids* from a radiant at $104° + 29°$.

Mr. P. M. Ryves, observing near Exeter on December 10, between $11^h\ 45^m$ and $14^h\ 15^m$, saw 54 meteors, of which 27 were *Geminids*. He noticed that some very rapid small meteors radiated from *Leo Minor* or *Ursa Major*. The sky was very clear, with the exception of a few small clouds which did not materially interfere with observation.

The following is a list of the real paths of bright meteors observed in England during the past year :—

Date. 1901.	G.M.T. h m	Brightness.	Height at Fir-t. Miles.	Height at End. Miles.	Length of Path. Miles.	Velocity per Sec. Miles.	Radiant Point. α ° δ °	Observers.
Jan. 13	10 35	F	61	52	54	8	149 − 12	3
28	9 18	½ = ☽	76	16	61	18	106 + 52	4
Feb. 13	10 41	♀	56	26	36	moderate	72 + 41	2
27	8 52	F	103	57	120	12	165 + 6	3
Mar. 6	7 25	F	84	27	66	slow	51 + 43	8
April 1	9 44	F	69	12	67	slow	129 + 25	7
19	9 28	♀	56	52	40	25	226 − 17	3
Aug. 11	11 2	2 + ♀	95	56	64	rapid	45 + 58	5
15	10 48	♃ − ♀	81	61	37	41	52 + 53	2
Sept. 14	8 45	> ♀	66	26	83	20	345 + 1	20
Nov. 10	6 45	½ = ☽	64	55	73	24	55 + 7	10
13	6 53	½ = ☽	90	52	165	33	87 + 31	3
23	10 27	3 + ♀	70	25	57	slow	65 + 23	3
Dec. 4	5 36	= ☽	91	50	64	21	263 + 36	62
16	5 45	½ = ☽	68	54	51	20	105 + 37	3

The letter "F" in the column headed "Brightness" signifies that the object was a fireball with a brilliancy differently estimated by various observers.

A few of the principal meteoric showers observed during the year were as under :—

Date.	Radiant. α °	δ °	No. of Meteors.	Observer.	Name of Shower.
Apr. 20–21 ...	261	+36	8	W.F.D.	
21	270	+33	25	„	*Lyrids*
July 19–24 ...	290	+24	8	„	
Aug. 10	44	+58	55	„	*Perseids*
„	43	+56	15	H. J. Townshend	„
10–20 ...	335	+73	13	W.F.D.	
10–21 ...	290	+53	10	„	
10–21 ...	350	−14	10	„	
10–22 ...	335	+ 1	15	„	
10–22 ...	310	+61	11	„	
11	45	+58	49	„	*Perseids*
„	46½	+57	14	A. King	„
11–12 ...	50	+58	30	W. H. Milligan	„
12	45	+54	10	H. J. Townshend	„
„	47	+58	13	A. King	„

Date.	Radiant. α	δ	No. of Meteors.	Observer.	Name of Shower.
Nov. 14–15 ...	152°	+23°	12	J. H. Bridger	*Leonids*
,, ...	150	+23	...	E. C. Willis	,,
14	149	+23	6	A. S. Herschel	,,
15	150	+23	12	,,	,,
14	150	+22	...	T. H. Astbury	,,
,, ...	150¾	+21½	88	W. Upton	,,
15	151	+21¼	21	,,	,,
14	149	+22¾	7	W. H. Robinson	,,
14	151	+23	19	W. C. Brenko	,,
14	149	+24	63	,,	,,

Though the shower of *Leonids* was a moderately rich one the photographic results appear to have been very meagre. Mr. H. C. Wilson secured one *Leonid* trail at Northfield, Minn., and this with two others obtained in 1898 appear to prove that the radiant is not an area, but a point at α 10^h 6^m, δ +22° 18′.

From Columbia College Observatory Professor J. K. Rees reports that the plates taken on November 14 show a number of trails, including a remarkable one left by a brilliant *Leonid* which appeared on November 14, 15^h 58^m, and left a streak for 20 seconds.

Professor W. H. Pickering, of Harvard, remarks (*Popular Astronomy*, 1902 January) that the observations of the *Leonids* in 1901 appear to induce the belief that the 33·25-year period must be abandoned, and that the swarm has followed an orbit since 1698 whose period is very nearly thirty-four years.

Remembering that brilliant displays of *Leonids* were seen in 902, 1002, 1202, and 1602, it seems possible that a rich return may be visible in 1902 November, though the Moon will be full at the time. The year 1902 is a notable one in connection with the interesting history of this meteoric system, since it is just 1000 years ago—in 902—when it was first observed and recorded.

Telescopic Showers of Daylight Meteors.—Mr. J. Coles, Liphook, Hants, has published an observation made on the afternoon of September 18. While viewing *Arcturus* in a 7-inch Newtonian reflector he noticed a number of bright objects rapidly crossing the field from W. to E. They appeared at the rate of about twelve per minute, and were assumed to be meteors. But phenomena of this kind are comparatively frequent, and are really produced by terrestrial objects floating high in the air. They consist of buoyant seeds such as thistledown, or of snow showers, or flights of gossamer webs, and are quite different from the telescopic meteors with which comet-seekers and observers of variable stars are familiar. That the objects discerned by Mr. Coles and by many others in previous years were not meteors is certain. Mr. Denning has witnessed about a dozen of these

daytime showers while making solar observations, and noticed that the irregular rate and direction of motion of the objects, combined with their aspect and general behaviour, proved them to be sunlit, comparatively near the Earth's surface, and borne along in wind currents which introduced all the vagaries observed. W. F. D.

Solar Activity, 1901.

There can be little doubt that the past year has seen the minimum of the current solar cycle. As it regards both spots and faculæ, the Sun has been more entirely quiet than in any year since 1878. On 297 days out of the 365 it was entirely free from spots—that is to say, on 81 per cent. as compared with 50 in the previous year. Only two groups of any importance were noted, both of which formed on the farther side of the Sun, and came into view first at the east limb. The first of these appeared by a curious coincidence on the day after the total solar eclipse, a great prominence over the place of the spot having been conspicuous during the eclipse. This group was visible during two apparitions, being seen from May 19 to May 30, and again from June 16 to June 26, though in much diminished extent. A fine regular spot ran its course from November 13 to November 25. The other groups were all insignificant and short-lived. The longest periods of complete quiescence were from March 11 to May 18, 69 days; and from July 25 to October 6, 74 days. The mean daily spotted area for the year will scarcely exceed, if indeed it does at all, that for 1878, which was twenty-four millionths of the Sun's visible hemisphere, or one-sixtieth of that shown during the last maximum.

The Prominences.—The slight falling off in the mean daily numbers of prominences which was noticed in 1900 appears to have continued and to have become much more marked during 1901.

The results derived from observations carried out on a uniform plan at Kenley for the two years are as follows:—

	1900. Per diem.	1901. Per diem.
North hemisphere	3·17	2·56
South ,,	3·61	3·06
Total mean number	6·78	5·62

The average size of the prominences also shows a decrease in the ratio of five to four.

The southern hemisphere still continues to be more active than the northern in the proportion, roughly, of six to five; and the distribution of the prominences in latitude during 1901 shows but little change compared with the previous three or four years. By far the largest number have occurred between the

parallels of +35° and +55° in the northern hemisphere, and between −45° and −55° in the southern hemisphere, these zones of maximum activity occupying nearly the same positions as in 1900. The southern zone has, however, encroached a few degrees upon the barren polar region, and the parallels +60° and −60° now mark symmetrically the limits of prominence activity towards the poles.

Herr Fenyi, at Kalocsa, records seventeen prominences of not less than 100″ in height observed during the year; and one eruption, on June 1, which attained the height of 431″ in fifteen minutes.

No large prominences of the eruptive class were seen at Kenley, and only one metallic prominence was recorded; this occurred on January 20 in latitude −6°. E. W. M. and J. E.

Total Solar Eclipses.

1898 *January 22.*

Two important papers on the spectroscopic results obtained at this eclipse, by Sir N. Lockyer and Mr. Evershed, have been published during the year. (*Phil. Trans.*, 197A.)

Sir N. Lockyer discusses the spectra of both the corona and the chromosphere, and arrives at the conclusion, confirmatory of his previously expressed opinion, that many very strong chromospheric lines are not represented among the Fraunhofer lines and *vice versâ*, and that the chromosphere is, therefore, not the seat of the Fraunhofer absorption.

Mr. Evershed, on the other hand, reaches the conclusion that practically every strong dark line in the solar spectrum is present as a bright line in the flash spectrum, and, conversely, that almost all the flash spectrum lines (except those of hydrogen and helium) coincide with dark lines in the solar spectrum. He thence concludes that the flash spectrum may be considered to represent the upper, more diffused, portion of a stratum of gas which, by its absorption, gives the Fraunhofer dark-line spectrum.

This fully confirms the views held by Professor Frost based on his discussion of the spectrum observations of the eclipse of 1900 May 28, made by the Yerkes Observatory party.

In his examination into the chemical origins of the flash spectrum lines Mr. Evershed arrives at the result that no element having a higher atomic weight than 92 is certainly present, while almost all the known metals with atomic weights less than 60 can be identified. This is quite in accordance with previously accepted opinions, with one remarkable exception—namely, barium, which metal is known to be present in the Sun and is generally supposed to have been detected in the chromosphere. Sir Norman Lockyer includes it in his list of elements,

of which the strongest arc lines are visible in the chromosphere spectrum and some of its lines have long since been observed thickened over spots. The presence of barium in the chromosphere, among elements of much lower atomic weights, seems quite analogous to the extended diffusion of calcium, and neither phenomenon presents any difficulty if we admit a dissociation theory.

1901 *May* 18.

The observations of this eclipse, which, owing to the long duration of its totality, was looked forward to with unusual interest, proved somewhat disappointing, as the weather conditions were decidedly unfavourable. Three British parties took part, Mr. Newall from the Joint Permanent Eclipse Committee, and Mr. Dyson and Mr. Maunder from the Royal Observatory, and a preliminary account of their results has been published.

Mr. Newall, who was stationed at Sawah Loento, in Sumatra, attempted an extensive series of observations, including photographs of the corona both direct and with a polariscopic camera, spectrum photographs with flint, quartz, and grating spectrographs, and a further attempt to get some indication of the rotation of the corona by measuring its velocity in the line of sight. Light clouds obscured the Sun at the time of totality, and the spectrum photographs were thus prevented from being completely successful, though some interesting plates were secured, which will doubtless prove worthy of detailed study. The amount of cloud was not sufficient to seriously affect the direct photographs of the corona, of which a good series was obtained. The corona proved to be of the typical Sun-spot minimal type, with extensive polar streamers round the south pole and shorter ones round the Sun's north pole. The most striking feature is the great disturbance that was evident in the eastern equatorial region, where there was a series of remarkable arches presenting an appearance of connection with a large prominence.

Mr. Dyson, who was assisted by Mr. J. J. Atkinson, was stationed on a small island off the coast of Sumatra and had with him the Thompson coronagraph, some of the slides of which were provided with an occulting shutter of the type used in former eclipses by Mr. Burckhalter, and flint and quartz spectroscopes as used before in India in 1898 and in Spain in 1900. Here also light cloud somewhat vitiated the observations, though apparently no very extensive damage was done to the direct photographs. The results obtained with the spectroscopes do not appear to exhibit any novel features. The corona spectrum shows no new lines, and the chromospheric spectra are of the same character as observed before.

Mr. and Mrs. Maunder were stationed on the island of Mauritius, and in conjunction with the staff of the Royal Alfred

Observatory undertook an extensive programme, chiefly in the form of coronal photographs, with instruments of varying focal length and aperture. Though there was no actual cloud, the definition is described as having been very poor, and a considerable amount of "boiling" was observed at the Sun's limb previous to totality. A large number of successful photographs were, however, obtained.

If the British observers were unfortunate in the weather, the American parties were still more so, and the large expedition from the U.S. Naval Observatory, including in their number Professor Barnard, found their view of totality entirely obscured by clouds. This is all the more to be regretted seeing that Professor Barnard had made preparations for obtaining coronal photographs with a lens of 61½ feet focal length, using plates 40 inches square. With the long exposure that could have been given and Professor Barnard's well-known photographic skill, it is certain that the resulting pictures would have been of exceptional interest and beauty.

The Naval Observatory party had also detachments at two other places, which were more fortunate than the main body. Professor Eichelberger, Dr. Humphreys, and Mr. Peters were at Fort de Kock, the only station in Sumatra where the weather was perfectly clear, and the last-named observer is known to have secured a good set of photographs with a 40-foot telescope. The Lick Observatory party, under the direction of Professor Perrine, was at Padang with an extensive equipment comprising Professor Schaeberle's 40-foot telescope, spectrum, and polariscopic cameras, and a battery of cameras for detecting the presence of an intra-mercurial planet. The long totality of this eclipse made it a unique opportunity for this search, and in spite of the presence of cloud some interesting evidence, apparently all of a negative nature, was obtained. Professor Perrine reports that the best plate showed 37 stars down to about 8·6 visual magnitude, and another one 28 stars down to magnitude 8·8. The failure to find a new planet will not, however, cause any surprise, as, seeing the close scrutiny to which the surface of the Sun has been subjected for many years, and seeing that it is almost inconceivable that a planet inside *Mercury* should not transit the Sun's disk at comparatively frequent intervals, it seems highly improbable that such a body could have escaped detection.

The spectrum photographs taken by this party show a strong Fraunhofer dark-line spectrum in the outer region of the corona, an appearance often before observed, especially when using instruments of considerable light grasp and small dispersion. Professor Perrine considers that his results indicate that the light of the outer corona is almost entirely reflected sunlight, while that of the inner corona emanates from incandescent matter; and he thence concludes that the extensions and streamers are due to matter ejected radially from the Sun at high velocities, such matter being gaseous and incandescent while near the solar

surface and becoming solid at a certain distance. He thus arrives at a theory of the corona similar to that originally propounded by Schaeberle. In connection with this question it may, however, be remarked that previous observers, basing their opinions upon a discussion as to the position in the spectrum of the point of maximum photographic intensity of the coronal light, have reached the conclusion that only a small portion of the light, even of the outer corona, is due to sunlight reflected from small particles, and are thus at variance with Professor Perrine. Another American party, from Amherst College, under the direction of Professor D. P. Todd, were located in Sumatra with an elaborate battery of instruments, but were unfortunate in their weather and obtained but meagre results.

A French party, under the direction of the Comte de la Baume Pluvinel, was at Padang and made some successful observations. No detailed report of their work has, however, yet been published. The same may be said of the large party of Dutch astronomers, and also of the Russian and Japanese observers.

In conclusion, we may say that this eclipse marks little, if any, advance in our knowledge of solar physics. The spectrum photographs secured are apparently not so good as those got either in 1900 or in 1898, and, while detailed examination may reveal points of interest, it is not probable that this scrutiny will reveal anything of fundamental importance. The apparent inter-relation between a disturbed region of the corona and a prominence is interesting, as any connection between the two phenomena was not previously established with certainty, and may serve to throw some light on the physical constitution of the corona.

E. H. H.

Nova Persei.

A new star was discovered in *Perseus* on February 21, $14^h\ 40^m$ G.M.T., by Dr. Anderson, of Edinburgh. It was then of 2·7 magnitude and shone with a bluish-white light. Its approximate place for 1901·0 was R.A. $3^h\ 24^m\ 25^s$, Dec. $+43°\ 41'$. The news was telegraphed to Kiel and appears to have been circulated to most European observatories, and to that of Harvard College for distribution in America by the early evening of February 22.

The star was seen on February 22 (before news of its discovery by Dr. Anderson had reached them) by Mr. Gregg at Hastings, Mr. Gore at Dublin, Mr. Laursen-Nordvig in Denmark, Messrs. Baliasny, Kvasnikoff, and Sviatsky near St. Petersburg.

Of more interest is the announcement by Dr. Glasenapp that the star was seen on February 21, $9^h\ 50^m$ G.M.T., by Mr. Borisiak, a boy of sixteen, at Kiew, who gave the magnitude as 1·5, and wrote to Dr. Glasenapp before the news could have reached Kiew. At the instance of the editor of the *Astronomische*

Nachrichten enquiry was made as to whether any mistake in date could have been made, and he was satisfied that the only error made was in the magnitude of the star, which was probably over-estimated.

Magnitude.—At discovery by Dr. Anderson the magnitude was $2^{m}\cdot7$. Three observers, Messrs. Grimmler, Plassmann, and Schwab, state they were observing the part of the sky in which the Nova appeared on February 21 from 7^{h} to 10^{h} 30^{m}, and consider that the star would not have escaped their notice had it then exceeded $3^{m}\cdot4$. Against this must be set Mr. Borisiak's observation given above. No trace of the star is shown on Harvard College photographs taken on February 18 and 19, which showed stars down to $10^{m}\cdot4$, and a photograph taken by Mr. Stanley Williams on February 20, 11^{h} G.M.T., only 28 hours previous to Dr. Anderson's discovery, showed stars of 11^{m} to 12^{m}, but did not show the Nova.

From February 23 onwards hundreds of observations have been made of the magnitude of Nova *Persei*, and are to be found in the astronomical periodicals and in the circulars of the Lick and other observatories. The light curve from February 19 to April 30 determined from 527 observations, mostly published in *Astronomische Nachrichten* and *Bulletin de la Soc. Astron. de France*, is given by Mr. Child (*Monthly Notices*, vol. lxi. p. 483). A collection of the observations as well as a diagram of the light curve is given by Mr. Wilson in *Popular Astronomy*, vol. ix.

The most complete discussion of the magnitudes yet published is given by the Rev. J. G. Hagen, S.J., as supplementary notes to the "Atlas Stellarum Variabilium" of the Georgetown College Observatory. The new star, which, on February 20, 11^{h}, was $<11^{m}$, and was $2^{m}\cdot7$ on February 21, 14^{h} 40^{m}, rapidly increased to $0^{m}\cdot1$, which it appears to have reached by February 23, 5^{h} G.M.T., and to have remained at this magnitude for about 24 hours. Its magnitude then diminished, at first rapidly and afterwards more slowly, so that it was $1^{m}\cdot0$ about February 25, 7^{h} G.M.T., $2^{m}\cdot0$ on March 1, $3^{m}\cdot0$ on March 10 or 11, and $4^{m}\cdot0$ on March 18. The further decline to $6^{m}\cdot0$, which was reached early in June, was accompanied by oscillations sometimes reaching to nearly two magnitudes, and of period varying from two to five days. The first pronounced *minimum*, though smaller oscillations may have occurred earlier, was on February 19, when the magnitude was $5^{m}\cdot2$. Other minima were on March 22, 25, 28, &c. These oscillations do not seem to have been maintained to any great extent after the early part of June, though as yet the observations have not been collected and discussed. The diminution of magnitude continued slowly to the end of the year, when the Nova was $7^{m}\cdot0$ or a little brighter.

Colour.—An account of the change of colour of Nova *Persei* from February 22 to April 30 is given by Mr. Osthoff in *Astronomische Nachrichten*, 3751. The colours attributed by different observers till May are given in *Popular Astronomy*. At its dis-

covery Dr. Anderson described the colour as bluish-white. There is some divergence among the observers, but it would seem that on February 23 and 24 it was white, a pale yellow on February 25 and 26, becoming orange by the beginning of March and red by March 3 or 4. From March 19, when the oscillations in magnitude began, the colours were orange at a maximum and red at a minimum. It may be noticed that the photographic image of the star was much stronger than that of a red star of similar visual magnitude, possibly in consequence of the large amount of ultra-violet light as shown in the spectrum. According to a paper of Mr. Robinson's (*Monthly Notices*, vol. lxii. pp. 193–199), the changes in photographic magnitude followed closely those of visual magnitude.

Measures of position; proper motion; parallax, &c.—The Nova appears to have been observed with the meridian instruments of nearly every observatory soon after the announcement of its discovery. Measures of its distance from neighbouring stars were made at the Yerkes and Lick Observatories, and photographs of the field for use in determination of the position, proper motion, and parallax appear to have been generally taken. As yet there has not been time for any complete discussion, but it appears probable from the results of Mr. Bergstrand and others that the star can have but a very small parallax, probably beyond the limits of measurement. It was announced by Mr. Bergstrand that the Nova had a considerable proper motion, but his later photographs do not support this view. In this connection attention may be drawn to Mr. Ceraski's note in *Astronomische Nachrichten*, 3755, that a photograph taken 1899 January 30 showed a 12th-magnitude star whose coordinates relatively to the present position of the Nova are $+0^s{\cdot}31$ in R.A. and $-7''$ in Dec. This star has not been seen since the Nova appeared.

Spectroscopic observations.—The spectrum of the Nova has been observed and discussed in the *Monthly Notices* by the Rev. W. Sidgreaves and by Mr. McClean, in the *Proceedings* of the Royal Society by Sir N. Lockyer, in the *Astrophysical Journal* by Professor Hale and Professor Vogel, in a circular of the Lick Observatory (republished in *Astroph. Journal*) by Professor Campbell and Mr. Wright, in Harvard College Circulars by Professor Pickering, and in the *Astronomische Nachrichten* by Mr. v. Gothard.

The earliest photographs of the spectrum of Nova *Persei* were obtained at Harvard College on February 22. The star had a strong continuous spectrum and was traversed by thirty-three dark lines. The general appearance was that of the *Orion* type of stars. The spectrum was similar on February 23, but on February 24 the spectrum was a strong continuous spectrum traversed by bright lines accompanied on the violet side by very broad absorption bands. The contrast between the bright and dark bands was much stronger on February 25, on which day it

resembled that of Nova *Aurigæ* at the time of its discovery. The bright bands at H and K were crossed by fine dark lines (calcium), and a bright band at D was crossed by fine dark lines at D_1 and D_2 (sodium). These lines were only slightly displaced, and indicated a small velocity of recession. The maxima of the bright bands H_β, H_γ, H_δ were displaced 8 tenth metres to the violet, according to the measures of Professor Campbell and Mr. Wright. The changes in the appearance of the spectrum from February 27 to March 28 are shown in photographs given by Professor Hale in *Astroph. Journal*, p. 238, the most remarkable being the diminution of the bright lines on the red side of H_β. The dark bands accompanying the bright bands had changed by March 13 to numerous fine lines, of which the strongest had the greatest wave length, and was at the edge of the bright lines. The bright hydrogen lines were displaced about 5 tenth metres to the red. The dark hydrogen bands, the dark H and K bands (while they lasted), and the dark sodium band were all displaced to the violet by an amount $\Delta\lambda = -\cdot0046\lambda$ (Campbell and Wright).

The spectra underwent periodic changes in accordance with the changes in the star's brightness. At a maximum the continuous spectrum was stronger relatively to the bands. These changes are shown in Father Sidgreaves' paper in *Monthly Notices*, lxii. p. 146.

On July 9 it was announced by Professor Pickering that the spectrum of the Nova was that of a nebula and showed the usual nebular lines.

A spectrograph obtained at Lick on July 15 along with a comparison with N.G.C. 7027, and accompanied with an intensity curve, shows corresponding to each line in the nebula a band in the Nova, the bands having generally similar intensity curves. The principal maxima of these bands are at their violet edges, and are displaced from the normal positions of the nebular lines by an amount $\Delta\lambda = -\cdot00212\lambda$.

Nebulosity round Nova Persei.—On August 21 Messrs. Flammarion and Antoniadi announced that photographs of the Nova taken by them on the 19th and 20th showed a nebulous aureole. The matter was taken up by Dr. Max Wolf, who showed that the aureole was due to the peculiar character of the light of the star, but found what appeared to be a real but very faint trace of nebula about 5′ south of the Nova. As this was near the limit of his instrument he suggested that the region should be photographed by the Crossley reflector. Mr. Ritchey at the Yerkes Observatory obtained on September 20 with a 24-inch mirror and an exposure of $3^h\ 50^m$ a nebulosity round the Nova reaching to a distance of about 6′ and showing remarkable condensations in various parts. Mr. Perrine, of the Lick Observatory, by comparison of this photograph with one he obtained on November 7 and 8, showed that the principal condensations shown on Mr. Ritchey's photograph were in rapid motion,

amounting to no less than 11′ a year. This result was independently obtained by Mr. Ritchey from a photograph taken on November 9. In the *Astrophysical Journal*, vol. xiv., reproductions are given of photographs obtained at Yerkes on September 20 and November 13, which show these remarkable changes in the clearest manner.

The velocities indicated taken in connection with the probable small parallax of the Nova are comparable with the velocity of light. Mr. Max Wolf pointed out in *Astronomische Nachrichten*, 3753, that an assumption of a linear velocity equal to the velocity of light would imply a parallax of 0″·012. He threw out the suggestion that the luminosity was caused by the progress of an electric wave through nebulous matter at rest. Professor Kapteyn in *Astronomische Nachrichten*, 3756, offered as an explanation that the light from the star was reflected to us by the nebulous matter, and that the photographs show the light travelling out from the star.

Suggestions have also been made that an explanation of these high velocities is to be sought in the recent physical discoveries associated with the names of Professor Thompson and Sir W. Crookes. Other astronomers are of opinion that though the velocities are extremely great for ordinary matter, they are not inconceivably so when the extraordinary character of the Nova is contrasted with the everyday phenomena of solar prominences.

Conclusion.—It is too soon to enter into the hypotheses which have been put forward to explain the genesis and the subsequent behaviour of Nova *Persei* and of new stars in general. The questions are still *sub judice*. It may be remarked, however, that facts relating to Nova *Persei* have been collected in great volume and importance. The observations of the spectrum at an early date while the brightness was still increasing, the many observations of the spectrum since this time, and the discovery of the nebula in particular have put astronomers in possession of much fuller and completer data for attacking the interesting and difficult questions incident to the formation of *New Stars*. F. W. D.

Double Stars.

The present summary of references is arranged, as in former years, under the two heads, "Observation" and "Calculation." Abbreviated titles have been used as follows :—

M. N.: Monthly Notices, R. A. S.
A. N.: Astronomische Nachrichten.
A. J.: Astronomical Journal.
A. S. P.: Astronomical Society of the Pacific.
L. O. B.: Lick Observatory Bulletin.
P. A.: Popular Astronomy.

Observation.—Measures of some stars of special interest will be found :—

Sirius ...	R. G. Aitken, *A. S. P.* 79 ; *L. O. B.* 11.
Procyon ...	R. G. Aitken, *A. S. P.* 79 ; *L. O. B.* 11.
δ Equulei...	R. G. Aitken, *A. S. P.* 79 ; *L. O. B.* 11.
	W. Hussey, vol. v. *Lick Publications.*
β 883 ...	R. G. Aitken, *L. O. B.* 11.
	T. Lewis, *M. N.* 1901 May.
	W. Bryant, *M. N.* 1901 May.
	W. Bowyer, *M. N.* 1901 May.
R Pegasi ...	R. G. Aitken, *L. O. B.* 11.
	H. Struve, vol. xii. *Poulkova Publications.*
	T. Lewis, *M. N.* 1901 May.
	W. Bryant, *M. N.* 1901 May.
	W. Bowyer, *M. N.* 1901 May.

New Double Stars—

W. J. Hussey. A. J. 494. Third Catalogue of new doubles. 37 pairs under 1″·0.

W. J. Hussey. P. A. 1901 Feb., finds the principal star of β 168 a close double.

W. J. Hussey. A. S. P. 80, finds principal star of 66 *Tauri* a close double (0″·2) ; also of Σ 2339, which is 0″·2.

W. J. Hussey. L. O. B. 12. Fourth Catalogue of 100 new doubles. 67 pairs under 1″·0.

R. G. Aitken. L. O. B. No. 3. Third Catalogue of new double stars. 43 pairs under 1″·0. The mean results are also in *A. N.* 3731.

R. G. Aitken. A. S. P. 81, finds the principal star of β 986 a close double.

Rev. T. E. Espin. A. N. 3717, 39 new doubles, 8 under 5″.

Measures of Known Pairs—

Rev. T. E. Espin. A. N. 3717. 84 wide neglected doubles.

L. Brenner. A. N. 3753. Measures of γ *Andromedæ.*

J. Tebbutt. M. N. 1901 May. Measures of 28 pairs in 1899 and 1900.

J. Gledhill. M. N. 1901 June. 34 binary stars (9-inch refractor).

Royal Observatory, Greenwich. M. N. 1901 May. "Results of micrometric measures of double stars with the 28-inch refractor in 1900." 368 stars ; 218 under 1″·0.

W. A. Cogshall. A. J. 505–6. Measures with the Lowell 24-inch of stars discovered by Dr. See.

E. Doolittle. A. J. 486. Motion in the system *Krueger* 60.

R. G. Aitken. L. O. B. 11. Measures of 194 double stars in 1900–1.

W. J. Hussey. A. S. P. 80. Note on *Capella.*

Cape Double Star Results. M. N. vol. lxi. No. 9. 500 southern stars, 52 of which are new pairs.

E. Doolittle. Measures of 900 double and multiple stars made at the Flower Observatory.

Hermann Struve. Measures of 900 double stars made with the 30-inch Poulkova refractor from 1885 to 1895. Vol. xii. series ii. *Poulkova Publications.* 76 stars under 0″·5; 127 between 0″·5 and 1″·0; 164 between 1″·0 and 2″·0; the remainder being over 2″.

Calculation.—The following papers dealing with calculation and general literature have appeared in the course of the year :—

ζ Sagittarii	R. G. Aitken, *P. A.* 1901 Feb.; orbit, period 21·2 years.
ξ Boötis ...	G. C. Comstock, *A. J.* 503; orbit, period 172 years.
η Cassiopeiæ	G. C. Comstock, *A. J.* 512; orbit, period 500 years.
Σ 3062 ...	J. Larsen, *A J.* 505–6; orbit, period 114·2 years.
Σ 1639 ...	T. Lewis, *M. N.* 1902 Jan.; orbit, period 180 years.
β 107 ...	S. W. Burnham, *P. A.* 1900 Dec ; Note on.
β Cassiopeiæ	S. W. Burnham, *P. A.* 1900 Dec.; Note on.
β 182 ...	S. W. Burnham, *P. A.* 1900 Dec.; Proper motion of.
Σ 325 ...	W. Hussey, *P. A.* 1901 Feb.; principal star has a proper motion of 0″·16 in 302°.

Special mention must be made of vol. v. of the *Lick Observatory Publications.* In this volume Professor W. Hussey has collected all the Otto Struve pairs (OΣ) in order, and gives the whole history of each pair, its catalogue place, the micrometric measures (with references to original sources), and, where possible, a discussion of these measures, accompanied with diagrams, which are also valuable as enabling observers to tell at a glance what stars require observation. Beyond the actual collection and arrangement of measures of other observers, Professor Hussey has examined in all 612 stars, made measures of 547 of them, and found 65 to be single. The work is modelled on the Yerkes volume, and is, like it, a standard of reference.

T. L.

Photometry and Variable Stars.

The past year has been characterised by great activity in the department of variable stars, and the following new variables have been announced. The list does not pretend to be exhaustive.

Identification.			R.A. h m	Dec. ° ′	Epoch.	Discoverer.	Reference, &c.
69	1901	Andromedæ	0 43·5	+33 35	1855	Anderson	*A. N.* 3698
74	1901	Persei	3 2·7	+44 29	1900	Guthnick	„ 3720
68	1901		3 17·8	+43 39	1855	Williams	„ 3698
75	1901	„	3 24·8	+44 19	1890	Deichmüller	„ 3720
71	1901	Aurigæ	5 18·3	+42 18	1855	Williams	„ 3708 short period
			10 16·7	−41 44	1875	Roberts	*A. J.* 508 Algol type
77	1901	Herculis	16 25·8	+ 7 9	1855	Anderson	*A. N.* 3738
76	1901	Ophiuchi	17 49·6	+11 11	1855	„	„ 3731
			18 32·8	+43 50	1855	Williams	„ 3670
73	1901	Scuti	18 46·3	−12 47	1855	Ceraski	„ 3718 Algol type
			18 54·3	+34 45	1855	Williams	*A. N.* 3671
72	1901	Lyræ	19 7·6	+33 10	1855	Ceraski	„ 3718
2	1901	Cygni	19 12·2	+49 55	1855	Anderson	„ 3692
93	1901		19 14·4	+19 25	1900	Schwab	„ 3748 Algol type
1	1901	„	19 28·0	+28 0	1855	Williams	*A. N.* 3687
			19 43·3	+48 49	1900	Hisgen	„ 3669
78	1901	„	20 18·0	+42 46	1855	Williams	„ 3740 Algol type
96	1901	„	20 49·0	+29 52	1855	„	*A. N.* 3751–2
20	1900	„	20 59·8	+28 50	1855	„	„ 3675
94	1901	„	21 17·7	+41 52	1875	Deichmüller	„ 3751
95	1901	Pegasi	21 37·9	+24 21	1855	Anderson	& 3752
			22 4·6	+13 38	1855	„	„ 3670

Harvard College Observatory Circular, No. 54, gives a list of sixty-four new variable stars, the greater part being discovered from the presence of bright hydrogen lines in their photographed spectra. They are mostly situated in low southern declination. Thus the work of finding new variables in the southern hemisphere more than balances that in the northern.

An epoch in the progress of stellar photometry is undoubtedly marked by the publication of *A Photometric Durchmusterung*, which forms vol. xlv. of the *Annals* of Harvard College Observatory. This work contains the photometric measurements of all stars of the mag. 7·5 and brighter, north of declination −40°. There are also included the magnitudes of certain stars fainter than the limit mentioned, which are likely to be used as comparison stars for variables, and of other faint stars. The total number of stars included in this catalogue does not appear to be named therein, but an idea of the number may be surmised

from the fact that the catalogue proper consists of some 300 closely printed pages, each page having a double column of stars : on the average there may be perhaps eighty stars to a page. The following particulars are given for each star : (1) D.M. number. (2) Position in R.A. and Dec. for 1900. (3) D.M. mag. (4) Photometric mag. (5) Julian dates of observations. (6) Residuals found by subtracting the mean mag. from the individual measures. This catalogue, the result of years of labour on the part of Professor Pickering, must doubtless be of the very greatest value to all workers in variable stars, as well as for statistical purposes in connection with the distribution of stars, generally, in the heavens.

In the annual report of the director of the Harvard College Observatory it is stated that over 16,000 photometric comparisons have been made with the east equatorial ; several thousands of observations with the west equatorial. With the 12-inch meridian photometer, 54,448 settings have been made by the director. With the meridian photometer 33,316 settings have been made, bringing the total number with this instrument up to the huge number of 1,033,180. As regards photography, we learn that the 8-inch Draper telescope covers the whole northern sky to S. Dec. 12°·5, from two to four times a year. The Cooke lens covers all the sky visible at Harvard two or more times a month, while the transit photometer furnishes on every clear night a record of all stars crossing the meridian, and visible to the naked eye. Over 28,000 photographs have been taken in all at Arequipa. A further discussion of photographs of variable stars in clusters is in hand.

Dr. S. C. Chandler has announced that owing to pressure of work he is unable to undertake the preparation of a fourth catalogue of variable stars as he had hoped. The Council of the *Astronomische Gesellschaft*, however, are taking up the work, and ask for any unpublished observations which may be of use in determining light-periods to be sent in to them.

Dr. A. W. Roberts, of Lovedale, Cape Colony, has produced (*A. J.* 491–492) an excellent catalogue of southern variable stars, on the lines of Chandler's third catalogue. This is largely the result of his own long-continued observations ; and the high character of his work accordingly lends great weight to this catalogue, which includes ninety-four variables, all south of −30° Dec.

The variable star section of the British Astronomical Association has for the past two years been engaged in the systematic observation of a selected number of variable stars, of well-established or popular character. This working list contains forty-six stars embracing the different types of variation. Since 1900 January some 5000 observations have been made on the method of Argelander, and the results published from time to time in the *Journal B. A. A.* Co-operation in the work is the guiding principle, and with this in view the observations are concentrated on the above-mentioned limited number of stars.

Maps of the vicinity of each variable, together with lists of comparison stars and their brightness, have been issued to each observer. In addition, a uniform method of making and recording the observations is adopted. The number of workers is but few; but the results already achieved show how much may be done by co-operation in observation of variable stars. Professor Pickering very liberally furnishes photographs of the vicinity of certain variables as seen in the maps of the D.M. to any regular observers who wish for them. E. E. M.

Stellar Spectroscopy in 1901.

Spectrum of nebulæ.—Professor Campbell in his researches on the spectrum of Nova *Persei* has secured photographs of the planetary nebula *N.G.C.* 7027, and in the *Bulletin* No. 8 of the Lick Observatory he gives a reproduction which shows the narrow bright lines with admirable clearness. (Reprint in *Astroph. Jour.* xiv. 269, fig. 12.)

New stars and stars with peculiar spectra.—The phenomena presented by Nova *Persei* are dealt with in a separate note, p. 307.

Professor E. C. Pickering refers (*Ast. Nach.* **155**, 124) to the observations obtained of Nova *Aquilæ*, which was discovered in 1899 by Mrs. Fleming on the Draper Memorial photographs. In the later photographs the only lines seen in the spectrum are $H\gamma$ and 5007.

Professor Pickering gives the results of further investigations of the second series of hydrogen lines detected in the spectrum of ζ *Puppis* (*Ast. Nach.* **155**, 231; *Astroph. Jour.* xiii. 230).

Sir David Gill contributes a note on the spectrum of η *Argûs* (*Proc. R. S.* lxviii. 456; and *Monthly Notices*, lxi. App. [66].) It appears that the spectrum closely resembles that of Nova *Aurigæ*.

Classification of stellar spectra.—A discussion of the spectra of bright southern stars, which have been photographed at Arequipa with the 13-inch Boyden telescope as part of the Henry Draper Memorial, has been published in the past year. The work has been done by Miss Cannon under the direction of Professor E. C. Pickering; and the memoir forms Part II. of volume 28 of the *Annals of Harvard College Observatory*, Part I. being Miss Maury's discussion of the bright northern stars. The whole volume therefore "furnishes the principal facts regarding the spectra of all the brighter stars from the North to the South Pole;" Part I. dealing with 681 stars north of declination $-30°$, Part II. with 1122, chiefly in the southern hemisphere. The stars dealt with in Part II. are classified arbitrarily, and divided into thirty-one classes, which are designated according to the notation of the Draper Catalogue, modified so that intermediate classes can be indicated.

Velocity in the line of sight.—The most notable event in this branch of the subject is the publication of Professor Campbell's "Preliminary determination of the Motion of the Solar System" (*Astroph. Jour.* xiii. 80), based on the radial velocities measured at the Lick Observatory. The 280 stars available for this research were divided into 80 groups by combining neighbouring stars into one group. The following elements of the solar motion were obtained :—

$$\text{Velocity} = -19{\cdot}89 \text{ km/sec} \pm 1{\cdot}52$$
$$\alpha_0 = 277^\circ\ 30' \qquad \pm 4^\circ{\cdot}8$$
$$\delta_0 = +19^\circ\ 58' \qquad \pm 5^\circ{\cdot}9$$

Stars with large radial velocity.—Professor Campbell gives (*Astroph. Journ.* xiii. 98) the following examples :—

ε Andromedæ	−83·7 km/sec.	*θ Canis Majoris*	+96 km/sec.
μ Cassiopeiæ	−97·4	1 *Pegasi*	−76
ϑ Leporis	+95	*μ Sagittarii*	−76

Groombridge 1830 −95

Variable radial velocity.—Six stars with variable radial velocity have to be added to the list given in last year's report.

	α h m	δ ° ′	Discovered.	Reference.
ξ Piscium	1 48	+ 2 42	Lick Observatory.	Lick Obs. *Bull.* No. 4 (*Astroph. Journ.* xiv. 138).
ξ_1 Ceti	2 8	+ 8 23	„ „	„ „
σ Persei*	2 47	+52 22	„ „	„ „
ε Hydræ	8 42	+ 6 48	„ „	„ „
σ_1 31 Cygni*	20 10	+46 26	„ „	„ „
π Cephei	23 5	+74 51	„ „	„ „

* This star occurs in list of stars with composite spectra (*Ann. Harv. Coll. Obs.* xxviii. 93).

Orbits of spectroscopic binaries.—Orbits for the following stars have been published :—

α Ursæ Minoris	Hartmann	Berlin Akad. Sitzb. 1901. 444 *Astroph. Jour.* xiv. 52
ζ Geminorum	Campbell	„ „ xiii. 90
ζ Ursæ Majoris (Mizar)	Vogel	Berlin Akad. Sitzb. 1901, 534 *Astroph. Jour.* xiii. 324 2nd Paper. Arch. Néerl., Harlem 1901, 661
α Aurigæ	Campbell & Reese	Bull. Lick Obs. No. 6 *Astroph Jour.* xiv. 261
η Pegasi	Campbell & Crawford	Bull. Lick Obs. No. 5 *Astroph. Jour.* xiv. 202

New Instruments.—Professor Frost describes (*Astroph. Jour.* xv. 1) the new Bruce spectrograph of the Yerkes Observatory, and also the methods adopted in measuring and reducing the photographs. As examples of the results obtained, details are given of a photograph of *α Arietis*, for which a velocity of −13·66 km./sec. is deduced, in good agreement with the results obtained by Campbell −14·1 Vogel and Scheiner − 14·7 and Lord −14·0. Three photographs of *ε Leonis* give velocities +4·4, +3·5, +4·0 km./sec. ; thus the variability previously suspected is not corroborated, and the new results are in complete agreement with Wright's measures at the Lick Observatory.

Dr. J. Hartmann describes (*Zeitsch. f. Inst. Kunde*, xxi. 1901, p. 313) a careful set of observations of the effects of changes of temperature in the Potsdam spectrographs, and gives a description of the method of controlling the temperature of the large spectrograph to be used for the determination of the radial velocity of stars. An automatic arrangement has been adopted for switching the requisite electric currents through wires stretched inside the cover which enclosed the whole spectrograph.

Reduction of observations.—Dr. J. Hartmann gives a full account of the procedure adopted at Potsdam in measuring and reducing the photographed spectra of stars (*Ast. Nach.* **155**, 8).

H. F. N.

Revision of Taylor's Madras Catalogue for 1835·0.

The revision of an old catalogue must always be a source of anxiety to the revisor, for the policy of revision and the amount of revision required are inseparably mixed up, and are practically only to be justified by the final results.

Dr. Downing some years ago undertook the superintendence of the work involved in revising the star places of the Madras Catalogue. A succession of grants from the Royal Society has paid for the expense of the calculation, and the cost of publication has been borne partly by the India Office and partly by the Royal Society. It may be a truism to say that the two cardinal principles which underlie the value of such a work are, first and foremost, that the observations themselves and the data on which they depend are of such a character that when reduced on modern principles with modern data they compare favourably with modern results ; and, secondly, that the revision shall be sufficiently thorough to produce the best results from the originals. With reference to the first point, a study of the Madras volumes of observations can only tend to impress the reader with a very high opinion of Mr. Taylor and the enormous difficulties he had to contend with. Occasionally the Observatory was blown down about his ears ; everlastingly the marks on which his azimuth error depended caused him constant trouble.

In *Madras Observations*, vol. ii., p. 42, he says: "On a late occasion I paid a visit to the south mark, which is at the end of a very substantially built brick dwelling-house situated about 1½ mile from the Observatory; here I found a crack in the wall about two inches wide, which is just sufficient to account for the alteration above found; the north mark is a square (brick and chunam) pyramid of weather-beaten and rough exterior, thereby offering no means of detecting a small alteration of the foundation; but from the nature of the soil (a bed of loose sand) it is easy to believe that a considerable fall of rain (such as happened about this date) might have produced the alteration in question."

With reference to the second point, Dr. Downing remarks in his introduction: "The revision of a catalogue of 11,000 stars is a work of such magnitude that it was necessary to exercise the utmost vigilance in order to keep the expenses within reasonable limits, otherwise there would have been a danger of the work being left in an unfinished state. Hence the necessity of utilising, as far as possible, the existing material."

Whether the first or the second principle has been violated there is not sufficient evidence to give an opinion, but that the revised Catalogue is affected by considerable systematic errors is shown by the following comparison with Newcomb's Fundamental Catalogue given by Dr. Downing at the end of the Introduction:—

Limits of Dec.	$\Delta\alpha$.	$\Delta\delta$.	No. of Stars.
	s	″	
+75° to +65°	+·172	+0·44	62
65 „ 55	+·069	+0·69	63
55 „ 45	+·004	+0·91	62
45 „ 35	+·025	+0·78	100
35 „ 25	−·011	+0·51	101
25 „ 15	−·037	00	110
15 „ + 5	−·064	−0·05	117
+ 5 „ − 5	−·064	−0·14	109
− 5 „ 15	−·066	−0·07	91
15 „ 25	−·106	+0·34	86
25 „ 35	−·122	+0·42	52
35 „ 45	−·107	+1·07	54
45 „ 55	−·099	+2·22	40
55 „ 65	−·177	+1·88	41
−65 „ −75	−·199	+1·31	17

A considerable amount of the systematic error can of course be eliminated by application of corrections derived from the above table; and the re-reduction has both lessened the accidental error and eliminated the numerical errors of the original catalogues. W. G. T.

Latitude Variation.

Dr. Chandler has again taken up this subject. In *Astronomical Journal*, No. 489, he discusses all the material available with reference to changes in the annual elliptical component of the polar motions, and comes to the conclusion that the line of apsides is revolving from east to west, or in a direction contrary to that of the pole in its orbit, in a long period of some seventy-five years, or at a rate of about 5° per annum, and the length of the annual period oscillates about its mean value with a cycle of about sixty years.

In *A. J.*, Nos. 490 and 494, he again attacks the theory of polar motion, and finally concludes that it is the resultant of three separate terms, an annual term and two others, whose periods are respectively 428·5 and 436·0 days, motions circular and radii 0″·140 and 0″·090. The superpositions of these two periods is embraced in a cycle of something like seventy years. For five-sixths of the cycle the changes of period vary between 428·5 and 431·4 days, then suddenly shorten to minimum 415 days, and then rapidly lengthen. Similarly, the variations of the radius of motion are singularly asymmetrical. Dr. Chandler bases these assumptions on the discussion of thirty-seven series of observations extending from 1726 to 1900, the results of which are given in convenient tables. He also gives a diagram showing at a glance the comparison between theory and observation, and challenging observation to prove him wrong in a very few years, for the radius of motion is rapidly approaching its minimum value, 0″·05, and the period its minimum length of 415 days.

In *A. J.*, No. 511, and R.A.S. *Monthly Notices*, lxii. p. 122, he gives the results of his discussion of the observations made with the Greenwich reflex zenith tube, and remarks that the instrument "has unwittingly accomplished an even higher service to astronomy than that for which it was intended, and that in place of a fallacious aberration constant and an impossible stellar parallax it in reality contains a body of evidence of the highest value in relation to the constants of the latitude variation during the period which the observations cover. The old discussions are practically attempts to find four unknowns from two equations."

In *A. J.*, No. 513, he gives the determination of the constants of the polar motion from the observations by Molyneux at Kew with his zenith tube, and by Bradley at Wanstead with his zenith sector. He shows how he picked up a mistake of 1″·00 in the line of collimation, and at the same time quotes Bradley to show that the differences in the observations which were troubling him in 1728 were in reality largely due to what we now know as latitude variation, "the vibrations of which anomalies were palpable under his hand, so near did

Bradley come to the discovery of polar motion." And this with only a 2·8-inch object-glass and a few yards of iron tube and wire. W. G. T.

Geodesy.

The *Comptes Rendus* of the thirteenth Conference of the International Geodetic Association, which was held at Paris in 1900, published during the past year, contains a report by Major Burrard of the work of the Indian Trigonometrical Survey. The scheme of this work may be sketched by saying that main lines of triangulation cross the country, east to west, from Calcutta to Karachi, from Vizagapatam to Bombay, and another, north and south, passes through Dehra Dun, Agra, and Kalianpur, so that the country is divided into four quadrilaterals and the South Trigon, each of which is surveyed in detail by minor lines of triangulation. This main survey was finished some years ago, and the work has been extended westward into Persia and eastward into Burmah. Major Burrard refers in his report to this last-mentioned section. The survey of the Burmese peninsula consists at present mainly of a loop of triangulation which was along the western coast to Sandoway, then, turning south-eastward and then northward, passes almost along the meridian 96° east of Greenwich, and the circuit is completed by an east to west chain of triangles through Manipur. This loop is connected to the Indian Survey by two short chains of triangles, and it had been feared that the earthquake in Siam in 1897 must have had results to the serious detriment of this geodetic work. In the report on Indian geodesy made at the previous Conference of the Association in 1898 a fear was expressed that this earthquake might have severed the Indian and Burmese systems of triangulation, but that this could only be proved by the closing of the circuit when the line of triangles through Manipur was completed. Major Burrard reported in 1900 that this line was then finished, and that the re-observation of certain angles showed that no evil effects had been sustained. The closing errors of the great Burmese circuit are worth noting, as they show the degree of accuracy attained by the Indian Survey. The triangulation carried from the junction with the main Survey, southward and round the loop above described, ends in the side of a triangle at Manipur whose length, computed from the chain, is 79,530·40 feet. Its length, computed from the remainder of the loop west of Manipur, is 79,531·22 feet, the discrepancy being only 0·82 foot. The discrepancy in the azimuth of this closing side is $2''{\cdot}256$, and the geodetic position of the closing station as derived from the western chain is 60 feet different from that shown by the eastern observations. In his report to the Conference Major Burrard gave an analysis of the astronomical observations made at stations round Kalianpur to determine the

effect of local attraction, which have since been published in another form,* and have lately formed the subject of a paper presented by him to the Society. The result of these goes to show that the astronomical position of Kalianpur—that place having been chosen by Colonel Everest as the origin of the Survey because the surface of the ground around it gave no sign of deflection—derived from the latitudes and longitudes of the Survey cannot be regarded as absolute.

Sir David Gill's report on the Survey of Rhodesia, some details of which have already been mentioned in the *Monthly Notices*, led to a discussion at the Conference on the merits of the Jäderin base-measuring apparatus, Sir David having mentioned that the brass and steel wires which are the main feature of this apparatus are liable to molecular changes of length.

Attention must be called in this note to the determination of a short arc of longitude, Potsdam-Bucharest, made by Professors Albrecht and Borrass, of the Prussian Geodetic Institute, in which the Repsold registering micrometer, fitted to meridian instruments of the *coudé* type, was used for recording transits. The plan of this micrometer is that the observer causes a movable wire to remain in contact with the star-image and the time of transit is recorded automatically. Judging from the accordance of results shown in this determination, the apparatus must certainly be considered a success. It was expected that the method would diminish the amount of the personal equation, and the difference of this quantity between these observers, which had previously been greater than $0^s{\cdot}10$, became $0^s{\cdot}017$, and at the same time the mean error of the result of one night's determination of a difference of longitude fell from $0^s{\cdot}05$ to $0^s{\cdot}02$.

It may be well to record, though the work was begun earlier than 1901, that the officers of the French Service Géographique de l'Armée are repeating the historic operation of the year 1735 and are determining the length of a degree of the meridian at the Equator. This work is being done in Peru, and M. Gonnessiat, of the Lyons Observatory, has been put in charge of the Quito Observatory for purposes connected with this. At the same time a party of Russian geodesists are making the corresponding measure of a degree of the meridian in Spitzbergen, as Maupertuis did in 1736.

Regret may be expressed here for the death of Dr. Adolph Hirsch, Director of the Neufchatel Observatory, which took place in April last. Dr. Hirsch resigned the secretaryship of the International Geodetic Association, which he had held since 1886, in the year 1900. He had taken a leading part in European geodesy for many years. H. P. H.

* Professional Papers of the Survey of India, Department No. 5.

Papers read before the Society from March 1901 to January 1902.

1901.

Mar. 8. Observations of the partial eclipse of the Sun, 1900 November 22, made at Perth Observatory, Western Australia. Communicated by W. E. Cooke.

On the observation of position angles of polar double stars. R. T. A. Innes.

On the Oxford photographic determinations of stellar parallax: reply to the criticisms of Sir David Gill. H. H. Turner.

Occultations of *Jupiter* and his satellites, 1900 September 29, observed at Windsor, New South Wales. John Tebbutt.

Cape double star results, 1900. Communicated by Sir David Gill.

Observations of the *Leonids*, 1900 November 15–16, made at the Royal Alfred Observatory, Mauritius. Communicated by T. F. Claxton.

Description of a floating photographic zenith telescope and some preliminary results obtained with it. Bryan Cookson.

Note on Mr. Bryan Cookson's paper, "On the accuracy of eye observations of meteors, and the determination of their radiant points." H. C. Plummer.

The variable star *R Centauri*. Alex. W. Roberts.

On the new star in *Perseus*. A. Stanley Williams.

Further corrections to the Armagh Catalogue; with special reference to the "Anonymous" stars. J. L. E. Dreyer.

Notes on the spectrum of Nova *Persei* observed at the Stonyhurst College Observatory. Rev. W. Sidgreaves.

Positions of Nova *Persei* and 159 stars within 25′ distance from it; from a photograph taken at the University Observatory, Oxford. F. A. Bellamy.

Note accompanying photographs of the spectrum of Nova *Persei*. Frank McClean.

Observations of the new star in *Perseus* made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

1901.

Apr. 12. A first note on the Nova in *Perseus*. K. D. Naegamvala.

Note on some engraved charts of Pogson's proposed Atlas of Variable Stars. Rev. J. G. Hagen.

Meteoric showers from the region of α—β *Persei* and η *Aurigæ*. W. F. Denning.

Anomalous occultations of stars by the Moon. R. T. A. Innes.

A method of mechanically compensating the rotation of the field of a siderostat. H. C. Plummer.

Variations of *R Horologii* during 1900. Alex. W. Roberts.

Note on meridian observations of Nova *Persei*. A. Graham.

Further observations of the new star in *Perseus*. A. Stanley Williams.

The spectrum of Nova *Persei*, Note 2. Rev. W. Sidgreaves.

The spectrum of Nova *Persei*, Note 3; Nova *Persei* as a variable star with a variable spectrum. Rev. W. Sidgreaves.

Observations of Nova *Persei*. M. C. Sharp.

Further measures of double stars made at the Temple Observatory, Rugby, during the years 1895 to 1900. G. M. Seabroke, H. P. Highton, and E. C. Atkinson.

Observations of the new star in *Perseus* made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Formulæ and tables for correcting coordinates of stars on different photographs, especially different plates of the Astrographic Chart. H. H. Turner.

Further investigation of the "Two Method" personal equation. W. W. Bryant.

May 10. Second note on photographs of the spectrum of Nova *Persei*; correspondence with the spectrum of η *Argûs*. Frank McClean.

Results of double-star measures with the 8-inch equatorial at Windsor, New South Wales, in the years 1899 and 1900. John Tebbutt.

The visual spectrum of Nova *Persei*. Rev. A. L. Cortie.

The spectrum of Nova *Persei*, Note 4. Rev. W. Sidgreaves.

The green flash at sunset. J. Franklin-Adams.

Further observations of the new star in *Perseus* (3). A. Stanley Williams.

Further observations of Nova *Persei*. M. C. Sharp.

The Cambridge machine for measuring celestial photographs. A. R. Hinks.

1901.

May 10. Further observations of the new star in *Perseus*, made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Results of micrometer measures of double stars made with the 28-inch refractor of the Royal Observatory, Greenwich, in the year 1900. Communicated by the Astronomer Royal.

Additional note on the position of Nova *Persei*, and a comparison of photographic magnitudes of neighbouring stars with those of Fr. Hagen's Chart and Catalogue. F. A. Bellamy.

Note on the geometry of the siderostat. H. C. Plummer.

June 14. Observations of *Mars* made at Mr. Edward Crossley's Observatory, Bermerside, Halifax, during the opposition of 1900–1901. Joseph Gledhill.

On a modified form of revolving occulter for adapting the exposure of the Sun's corona to its actinic intensity at all distances from the Moon's limb. D. P. Todd.

The Oxford determinations of stellar parallax. Reply to Professor Turner. Sir David Gill.

Light curve of Nova *Persei*, 1901. Laurence Child.

Sun-spots and magnetic disturbance. William Ellis.

Observations of Nova *Persei* made at Birr Castle Observatory, Parsonstown. The Earl of Rosse.

Secular variation in the period of *R Carinæ*. Alex. W. Roberts.

The great Comet of 1901 as observed at the Royal Observatory, Cape of Good Hope. Sir David Gill.

The Oxford photographic determinations of stellar parallax. Further reply to Sir David Gill. H. H. Turner.

Measures of double stars made at Mr. Edward Crossley's Observatory, Bermerside, Halifax. Joseph Gledhill.

Corrections to reduce the revised Madras Catalogue of stars for 1835·0 to the Fundamental Catalogue of Auwers. A. M. W. Downing.

The *Lyrids*, 1901 April, observed at Cambridge. J. C. W. Herschel.

Further observations of the new star in *Perseus* (4). A. Stanley Williams.

Observations of the Sun during 1901 May 17, 18 and 20, at Mells, near Frome. Maures Horner.

Estimations of magnitude of Nova *Aurigæ* in 1899–1900, with the mean results for the years 1892–1900, from observations at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Further observations of the new star in *Perseus* made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

1901.

Nov. 8. Solar eclipse, 1901 May 18 (observations of the partial phase at Perth Observatory, Western Australia). W. E. Cooke.

The normal equations that arise in the usual schemes of observation for division errors, and their solutions. P. H. Cowell.

Errata in the revised Madras Catalogue of stars for 1835·0. A. M. W. Downing.

Mean areas and heliographic latitudes of Sun-spots in the year 1900, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India) and in Mauritius. Communicated by the Astronomer Royal.

A new form of reflecting telescope. Charles Anthony.

The green flash at sunset. W. H. Pickering.

Observations of Comet 1901 I. made at Perth Observatory, Western Australia. Communicated by W. E. Cooke.

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Nov. 8. Determination of Dr. Küstner's magnitude equation, from comparison of his meridian observations in zones $+24°$ to $+27°$ with measures of photographic plates taken at the University Observatory, Oxford. H. H. Turner.

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Experimental reduction of some photographs of *Eros* made at the Cambridge Observatory for the determination of the solar parallax. A. R. Hinks.

Further observations of the new star in *Perseus* made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

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Dec. 13. The observed motion and duration of the radiant point of the *Perseids*. W. F. Dunning.

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Apparent paucity of the *Leonid* stream. Rev. S. J. Johnson.

Contribution to the history of the reflex zenith Tube. S. C. Chandler.

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On a simple method of accurate surveying with an ordinary camera. H. H. Turner.

The *Leonids*, 1901. Observations made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

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On the velocity of *a Persei*. H. F. Newall.

1902.

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The attraction of the Himalaya Mountains upon the plumb-line in India. Major S. G. Burrard.

Period and light curve of 6685 *Y Lyræ*. A. Stanley Williams.

Σ 1639 *Comæ Berenicis*. Thomas Lewis.

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ADDRESS

Delivered by the President, Dr. J. W. L. Glaisher, on presenting the Gold Medal of the Society to Professor J. C. Kapteyn.

In awarding the Gold Medal of the Society to Professor J. C. Kapteyn for his work in connection with the Cape Photographic *Durchmusterung* and his researches on stellar distribution and parallax the Council have been able to place on record at the earliest opportunity their admiration of the noble services he has rendered to astronomy; and it is now my privilege to give a brief history of this great photographic catalogue and to refer to some of Kapteyn's other contributions to stellar cosmography.

In 1882 Gill tried the experiment of photographing the great comet of that year by means of a lens mounted in an ordinary camera, which was attached to the counterpoise of an equatorial. The successful results which he obtained suggested to him that with proper appliances photographic star maps could be constructed on any required scale and to any required order of magnitude.

During a visit to England in the early part of 1884 Gill obtained from Dallmeyer a rapid rectilinear lens of 6 inches aperture and 54 inches focus, this being the most suitable lens for astrophotographic work that Dallmeyer then had at his disposal. In September of the same year Gill applied for a grant from the Government Grant Fund of the Royal Society, partly for the purpose of photographing the solar corona and partly for making star maps by direct photography from the sky. With reference to the latter object he wrote: "I am most anxious to carry out this work for the southern heavens, being convinced that an accurate knowledge of star distribution according to magnitude can be more rapidly obtained in this way than in any other." The grant was made, and after some preliminary experiments systematic work was begun on April 10, 1885.

The first connection of Kapteyn with the work occurs eight months later. In a letter, written by him to Gill from Leyden on December 16, 1885, he made the following proposal: "If you will confide to me one or two of the negatives I will try my hand at them, and if the result proves as I expect, I would gladly devote some years of my life to this work, which would disburden you a little, as I hope, and by which I would gain the honour of associating my name with one of the grandest undertakings of our time." In a second letter, written a week later, after mentioning that at Groningen he is unprovided with an observatory, and sees no immediate prospect of obtaining one, he proceeds: "Now, after

your success in stellar photography, and especially after your letter in which you tell me, 'I am obliged to crave help where I can get it,' it has occurred to me that by measuring and reducing your photographs I could contribute very effectually towards the success of an enormous and eminently useful undertaking. Since then I have revolved the idea in my mind, and I have come to the conclusion that if you will let me, and if I can secure the necessary help, there is no one can be in better conditions to undertake the work than myself." In the concluding paragraph of the same letter, referring to the opinions of those he had consulted, he proceeds: "I am bound to say that they were not very enthusiastic about the matter; of course they thought the results once reached of immense value, but the drudgery to be gone through before these results are got into the form of a catalogue almost unbearable. However, I think my enthusiasm for the matter will be equal to (say) six or seven years of such work." As we shall see, Kapteyn did not overestimate his enthusiasm, which was to sustain him not only for six or seven years, but for nearly thirteen.

The actual photographing of the plates at the Cape, begun in April 1885, was continued without interruption until its completion at the end of 1890. There were several vicissitudes, principally relating to the lens. A second Dallmeyer lens of 6 inches aperture and 69 inches focus, which was expected to be superior to the first, was used for a time but found to be not so satisfactory. The portions of the sky, therefore, which had been photographed by it were rephotographed by the old lens, so that all the plates definitively used in the catalogue should be the work of the same lens.

The principal object which Gill had in view may be briefly described as the extension of the Bonn *Durchmusterung* to the south pole. To determine the exposure necessary for this purpose an area in the Bonn *Durchmusterung* was selected and photographed. The negative was then compared star by star with Argelander's chart, and the duration of the trial exposures was gradually increased till it was certain that every star in the selected part of the chart was shown as a measurable disc on the plate photographed from the sky. It may be mentioned that when the negative from the sky showed nearly the whole of Argelander's stars it also showed a great many more, as the Bonn *Durchmusterung* only professes to be complete as far as stars of the 9·2 magnitude.

Different kinds of plates were used during the five years over which the work extended. At first an exposure of an hour was required, but after about a year and a half more rapid plates were used, and the exposure was greatly reduced. At the time when the work was begun the difficulties were much greater than they would be now; the remarkable difference between the actinic and visual light of stars in different regions was unknown, as also was the variation of the sensibility of the plates due to moonlight

and other causes. Every area was photographed on two different nights in order to avoid the possibility of a speck on the plate being mistaken for a star.

I pass now to Kapteyn's work at Groningen: the measurements of the stars on the plates, their reductions, and the formation of the catalogue.

All the measurements for the catalogue were made by an instrument designed by Kapteyn for the purpose. The principle of this instrument, the object of which was to measure spherical coordinates directly from the plate, occurred to him very soon after he had received the first plates; it depends upon the obvious fact that by placing a plate at the proper distance (that is, at the focal distance of the photographic telescope), with the film farthest from the eye, it is possible to cover the stars in the sky with their corresponding images. If, therefore, we substitute for the eye an instrument by which spherical coordinates can be measured in the sky, we can measure these coordinates as well on the plate as in the sky.

This instrument was employed in the early part of 1887 to measure the circumpolar plates (which were those first taken) to the tenth of a minute of arc, and it was found to be rapid and convenient in use and to give results of the accuracy required for a *Durchmusterung*. It was also shown that the stellar images were sufficiently sharp to be easily measurable to a second of arc, and a parallactic instrument capable of giving results to this degree of accuracy was devised by Kapteyn and Gill. It was, however, not constructed, and the whole of the measurements were made, to the tenth of a minute of arc, by the same instrument by which the circumpolar plates had been measured. In using this instrument Kapteyn always fixed two plates, corresponding to the same portion of the sky, in the plateholder, one in front of the other, at the distance of a millimetre. Small motions were provided, by means of which the corresponding star images of the two negatives could be brought nearly, but not quite, to superposition, so as to appear in the telescope like double stars, and thus true star images were at once distinguishable from accidental specks on the plates. Of these two plates, in case of the slightest difference, the one on which the images were more dense was employed to act as the check plate; the other, mounted in front, was used as the measuring plate. The observations were made in a darkened room, the plates being illuminated from behind by a powerful lamp. The plates were square with a side of about six degrees.

In measuring the plates two observers always worked together, one at the ocular, one at the microscope of the hour circle. A clerk wrote down all the numbers called out by the two observers in ledgers prepared for the purpose. The observer at the ocular estimated the diameter, read off the declinations on the scale, and made the pointings for right ascension. These were read off by the observer at the microscope. Three or four

hours in the morning and three hours in the evening were generally devoted to the observations.

Every plate was observed twice, the two observations being quite independent. As soon as the second observation of a plate was completed the two observations were compared and the discrepancies examined. The second observations and the examinations and revisions were invariably made by Kapteyn himself.

The diameters of the images of the stars were estimated to tenths of a minute of arc. This unit, however, being found too large in practice was subdivided into thirds. From these diameters the magnitudes of the stars were determined by an empirical formula involving two constants, which will be referred to later.

Great pains were taken that no speck on the plates should be treated as a star; so careful indeed was Kapteyn in this matter that, as he states himself, many thousands of objects, by far the greater part of which are certainly true stars, have been lost to the catalogue. But it was his settled policy from the beginning not to introduce any object that was not a true star, and rather to lose ten real stars (of the very faintest class) than to incur the danger of introducing a single fictitious one.

Having now described in general terms the manner in which the plates were taken at the Cape, and observed and reduced at Groningen, I have to speak of certain special difficulties under which the work was carried out. As already mentioned a grant from the Government Grant Fund was made in 1885. The grant was repeated in 1886, but not in 1887. In that year the International Astrophotographic Congress had decided to undertake the work of forming a catalogue of stars to the 11th magnitude, and making charts of the heavens approximately to the 14th magnitude. It may have been thought by some that Gill's project was superseded by the decision of the Congress, but he himself never doubted the desirability of his own work, believing that in the existing state of astronomy its urgent need was increased rather than diminished by the results of the Congress. The completion of the work, however, without external assistance taxed even Gill's energy and resourcefulness to the utmost. Fortunately he persisted to the end; but he was unable to have the parallactic instrument constructed that would have measured the plates to a second of arc, and he did not carry the work north of the declination $-18°$.

Kapteyn obtained some assistance from the Dutch Government and from several Dutch institutions, which enabled him to retain the services of two and sometimes three assistants. Only one, however, remained with him throughout; the others, who were all at first quite inexperienced in work of the kind, frequently left after a short time, and these frequent changes added to the difficulties, and delayed the progress, of the work.

At length the catalogue was completed and published, forming three volumes of the Annals of the Cape Observatory. The

first volume bears the date 1896, the second 1897, the third 1900. The catalogue includes all stars down to about the 9·5 magnitude from −18° to the south pole. It has been mentioned that Gill's object was to extend Argelander's *Durchmusterung*, which was published in the middle of the last century, to the south pole, giving the magnitudes and approximate positions of the stars. Argelander's work, which included stars to the 9th or 10th magnitude, contained 324,188 stars; Schönfeld, who continued the catalogue from −2° to −23°, included 133,659 stars between these limits. The Cape *Durchmusterung* contains 454,875 stars between −18° and the south pole.

The catalogues of Argelander and Schönfeld contain 431,760 stars for the rest of the sky. The average number of stars for each square degree in the Cape, Argelander, and Schönfeld catalogues is 32·66, 15·19, and 18·21 respectively, so that the star density in the Cape catalogue is more than double as great as in Argelander's catalogue. The latter catalogue set a good example as regards freedom from errors, and there is every reason to believe that Kapteyn has fully maintained this high standard in the present volumes.

It is difficult to speak in too high terms of the zeal and ability displayed by Kapteyn during the years that he devoted to this catalogue. In the preface to the third and last volume Gill refers to him in the following terms: "It is my colleague and friend, whose name appears on the title page, to whom I am under the deepest obligation. At a time of great stress and discouragement he lifted from my shoulders a load of responsibility by his noble and spontaneous offer to undertake the measurement of the plates, the computation of the results, and the formation of the catalogue. He realised from the first the advantages and possibilities of the work, as well as the need for it in the present state of science, and he devoted over twelve of the best years of his life to the fulfilment of his undertaking. I now realise that my many other duties, and the difficulty of obtaining adequate assistance, would probably have compelled me to defer a great part of the work of the catalogue to the years of my retirement from official life, and might even have prevented its completion.

"I feel assured that Kapteyn has not laboured in vain, and that astronomers will duly appreciate what he has done for their science."

I may here also quote Newcomb's words: "This work of Kapteyn offers a remarkable example of the spirit which animates the born investigator of the heavens. . . . The years of toil devoted to it were, as the writer understands, expended without other compensation than the consciousness of making a noble contribution to knowledge, and the appreciation of his fellow astronomers of this and future generations." *

* *The Stars* (1901), p. 49.

Indeed we do appreciate his spirit and his work; and we are delighted to have the means of expressing our appreciation as a Society to Kapteyn in person here to-day. Sustained by his enthusiasm for the value of the work, he did not shrink from carrying out himself the monotonous and anxious labour of making the measurements and comparisons, so that the catalogue has the great advantage of being the work of a single mind, incessantly devoted to securing the best results that the data could afford. If the enormous amount of work required by the measurements may, perhaps, be described—as it was by Kapteyn's friends at the outset—as drudgery, it was quite otherwise with the methods of procedure, many of the questions to be dealt with being novel and full of interest, as this was the first photographic catalogue. The most important of these questions related to magnitude, and it fell to Kapteyn to have to investigate in much detail the relation between photographic and visual magnitudes.

By comparing the variation of star-density as determined from the plates with the variation as determined by the visual observations of Schönfeld and Gould, he found that in some regions the plates contained three times the number of stars given by Schönfeld in the same area, while in other regions Schönfeld's catalogue was the richer, containing almost double the number of stars shown on the plates. He also found that, corresponding to these variations in the numbers of stars, there were similar variations in their brightness, equal diameters on the plates being produced by stars of very unequal brightness, in different parts of the sky. It is possible, as suggested by Thome, that the cause of these variations is purely observational, the visual observer not including so many very faint stars in the richer, as in the poorer, regions of the sky; but Kapteyn considers any such explanation quite inadequate, and concludes definitely that the difference between the visual and photographic magnitudes is largely dependent upon the position of the stars relative to the Milky Way, and that, even when we take into account only stars of one and the same spectral type, those in the Milky Way are in general bluer than the stars in other regions of the sky.

The magnitudes were deduced from the diameters by the empirical formula $m = \frac{B}{d+C}$, d being the diameter of the image and B and C constants which were determined for each plate by comparing a number of stars with the magnitudes in Schönfeld's catalogue or in Gould's zone catalogue. This formula gives good results for stars between the magnitudes 6·5 and 9·5, but the uncertainty increases rapidly beyond these limits. The same formula has been used for the whole catalogue, the values of B and C being given for each plate, so that it will be easy to make the necessary corrections when a better formula is known or even to fall back, if need be, upon the quantities

really measured—that is, on the diameters of the stars on the plates.

With respect to the limits of magnitude to which the catalogue may be considered complete, Kapteyn concludes that the whole catalogue is complete to stars of the photographic magnitude 9·2, and that it will be found practically complete in or near the Milky Way to stars which in the scales of Gould, Schönfeld, and Thome are of the magnitude 9·5, and for the rest of the sky to stars actinically equivalent to these.

In the catalogue itself it is noted when a star is suspected of being double, or variable, or nebulous, and references are given to the principal catalogues in which a star has previously appeared. A characteristic feature of the work is the extreme fulness of detail of the introductions, which, in addition to everything that can render the catalogue more serviceable, contain the results of extensive comparisons with catalogues of precision; such, for example, as lists of stars of the magnitude 9·0, or brighter, not found in the plates. Since the publication of the catalogue Kapteyn has been occupied with the formation of lists of errors in the other catalogues, lists of stars with large proper motions, and of variables, as also with an examination of the colours of the stars in the Milky Way. These investigations are practically complete. I may mention that it was by such comparisons that the star with greatest known proper motion (8″·70) was discovered.

Thanks to the enthusiasm and perseverance of Gill and Kapteyn, we are now in possession of the Cape *Durchmusterung*. No doubt in the fulness of time it will be superseded by the astrographic chart of the heavens, which will not only include many more stars, but give their places with precision; still it is a great matter that such a fund of information as the Cape catalogue supplies should have been rendered available at such a comparatively early date to the workers of our time. For the adequate treatment of the great cosmical problems relating to the magnitude and distribution of the stars, extreme accuracy of position is not required, and for all such investigations the Cape catalogue affords abundant material.

Before leaving the subject of the catalogue it should be mentioned that the whole of the measurements of the plates, and by far the greater part of the computations, were carried out in two rooms of the Physiological Laboratory at Groningen, which were kindly placed at Kapteyn's disposal by his colleague, Professor Huizinga. These two rooms constituted what was at that time a novel form of observatory—the possibility of which we owe to photography—in which the instrument was applied to the observation of the plates, instead of the stars themselves.

It is natural in this place to refer to an examination of the Cape *Durchmusterung* by Newcomb, who, after remarking that in the completeness with which it covers the field we have nothing equal to it in the northern hemisphere, expresses the

opinion that it can hardly be supposed that any object photographically brighter than the 9·5 magnitude has failed to be included. From a comparison with Thome's Cordoba catalogue he concludes that the limiting magnitudes of the different plates are in reality more nearly uniform than they were taken to be (in order to represent correctly both the brighter and fainter stars), and that it may be regarded as a fairly complete representation of the southern sky to a photographic magnitude of probably 10·0. This discussion of Newcomb's shows how greatly stellar research has been facilitated by the clearness and fulness with which the data of the catalogue have been presented.

At the time when Kapteyn made his proposal to Gill in 1885 he was occupied at Leyden with the determination of stellar parallaxes. His observations related to 45 stars, and he obtained 15 parallaxes, four of which had been previously determined by other observers. He employed a transit instrument and chronograph, and came to the conclusion that by his method he could obtain results comparable to those given by the heliometer. He suggested a plan for determining the parallaxes of all stars to the 5th magnitude. Each star was to be compared with two stars of the 8th magnitude. The whole scheme involved 16,640 complete observations, which he calculated could be carried out by two observers in eight years.

In 1889 Kapteyn proposed a much more comprehensive scheme—viz. that each plate for the astrographic catalogue should be exposed at three successive epochs of maximum parallactic displacement, being carefully preserved in the intervals of six months and developed after the third series of exposures. The plates would then furnish, in addition to the position of the stars, a first determination of their parallaxes. The proposal was not adopted for the catalogue work, but Professor Donner undertook to obtain with the astrographic equatorial at Helsingfors a series of plates for a definitive trial of this method of obtaining parallaxes *en bloc*. These plates Kapteyn measured at Groningen, and he obtained from them a first determination of the parallaxes of 246 stars. After giving a careful and detailed investigation of the results, he considers the possibility of a general *Durchmusterung* for parallax to include all stars down to the 10th magnitude, about 800,000 in number. This, he thinks, would secure about 500 well-determined parallaxes. Kapteyn's project breaks new ground and raises many questions; his own discussion, however, greatly narrows the issues for those who follow him upon these lines.

There is a great deal of other work connected with stellar parallaxes and proper motions upon which Kapteyn has been engaged, much of which still remains unpublished. As the direct determination of stellar parallax has not as yet given results on anything like the scale required for the purpose of judging of the relative distances of the stars, we are compelled to resort to the parallactic displacement caused by the motion of the solar

system in space. This parallactic motion, however, cannot be separated from the real proper motion for individual stars, but there is every reason to think that the real proper motion shows very little preference for determinate directions, and it may therefore be assumed that, in the mean results obtained from small groups of stars, these real proper motions will destroy each other, leaving only that part which is due to solar motion, and it is this parallactic displacement that gives the most reliable measure of the mean distance of the stars under consideration.

If we transform the proper motions from right ascension and declination to motions in the apical direction (*i.e.* along the great circle joining the star to the solar apex) and perpendicular to it, it is clear that the former is affected by the parallactic motion, but that the cross motion, perpendicular to the apical direction, gives the true component of the motion of the star. Led by these considerations Kapteyn undertook the labour of resolving in the apical direction and perpendicular to it the proper motions of the 2357 stars in Draper's catalogue of spectra, which are also included in the Bradley-Auwers catalogue, and were observed both in right ascension and declination. The stars were taken from Draper's catalogue because Kapteyn had decided to divide them into groups according to their spectral type, and to consider the groups separately. This division has shown that stars with small proper motions belong generally to the first type, and those with large proper motion to the second. It may be that the stars of the second type are moving faster than those of the first, but it seems more probable that they are less distant. This gives some support to Gould's suggestion that the Sun is a member of a star cluster.

I must necessarily pass over other important papers of Kapteyn's upon the distribution of cosmical velocities, the distribution of stars in space, the statistical relations between parallax, proper motion, and magnitude, and upon the luminosity of the stars. As a detail in his larger statistical researches he has deduced the position of the solar apex by a new method (Kapteyn's method), in which the apex is so chosen that the sum of the proper motions resolved in the direction of the anti-apex is a maximum, or that the sum of the motions perpendicular to this direction is zero. The resulting apex is $\alpha = 273°{\cdot}6$, $\delta = 29°{\cdot}5$ as deduced from 2640 Bradley stars and 699 Porter stars. The discrepancy from Porter's result (obtained by Kapteyn's method), $\alpha = 280°{\cdot}5$, $\delta = 49°{\cdot}3$, and from Campbell's result $\alpha = 277°{\cdot}5$, $\delta = 20°{\cdot}0$, derived from spectroscopic determinations of velocity in the line of sight (280 stars), only shows, what might have been expected, that considerable groups of stars in different parts of the sky are affected by common drift, which is quite distinct from parallactic motion.

I need not do more than merely refer to Kapteyn's simple and ingenious suggestion in explanation of the phenomena of Nova *Persei*, which has been discussed so recently, and with so much interest, in this room.

It will have been seen that one spirit runs through all Kapteyn's work, viz. an effort to treat the great cosmical problems comprehensively, and to apply to them general methods which, though not exact, may be expected to give information which would be quite unattainable by any procedure resting upon an absolutely sure foundation with respect to every individual star. Always occupied with the most effective means of attacking the great problems of the universe, he has never flinched from the heavy labour required to carry his ideas into practice; and it is very fitting that one whose mind has been from the first so much attracted by the more difficult questions presented by the statistics of the heavens should himself have contributed such invaluable material for the study of the subject which he has so much at heart.

The President then, delivering the medal to Professor Kapteyn, addressed him in the following terms:—

Professor Kapteyn, in placing in your hands this Gold Medal I wish specially to congratulate you upon the completion of the Cape *Durchmusterung*, and to express to you the hope that your life may long be spared, and that you may have health and strength to extract from this grand storehouse of your own formation many more of the great cosmical truths which it implicitly contains, and to enrich still further by your labours the important branch of our science to which you have devoted your life.

In handing to Dr. T. D. Anderson the Jackson-Gwilt medal the President addressed him as follows:—

Dr. Anderson, it is a great pleasure to me to hand you on behalf of the Society the Jackson-Gwilt medal in recognition of your discovery of both Nova *Aurigæ* and Nova *Persei*. Nova *Aurigæ* was discovered by you on February 1, 1892, when of the 4th magnitude, and but for your discovery it might have escaped observation. Nova *Persei* was discovered on February 22 of last year at 2.40 A.M., when of the 2·7 magnitude and low down in the sky. This early discovery of yours made it possible for Pickering to obtain its spectrum before its maximum was reached.

It is no small matter to have discovered one of these Novæ, but it is a veritable *tour de force*, such as *à priori* would have seemed almost incredible, to have discovered both, and I am delighted that we have the opportunity to congratulate you on your success and do honour to your astronomical zeal and intimate knowledge of the sky. Between your two discoveries several new stars had been found at Harvard, but all by photography.

I ought, perhaps, to refer at greater length to the number of variable stars—no less than thirty-eight—that you have discovered; but on the present occasion I should prefer to restrict myself to the subject of the award, your wonderful discoveries of the two great Novæ of our time.

The meeting then proceeded to the election of Officers and Council for the ensuing year, when the following Fellows were elected :—

President.

J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.

Vice-Presidents.

Sir William Abney, K.C.B., R.E., D.C.L., F.R.S.
W. H. M. Christie, Esq., C.B., M.A., F.R.S., Astronomer Royal.
E. B. Knobel, Esq.
H. F. Newall, Esq., M.A.

Treasurer.

W. H. Maw, Esq.

Secretaries.

F. W. Dyson, Esq., M.A., F.R.S.
E. T. Whittaker, Esq., M.A.

Foreign Secretary.

Sir William Huggins, K.C.B., LL.D., D.C.L., P.R.S.

Council.

Sir R. S. Ball, M.A., LL.D., F.R.S., Lowndean Professor of Astronomy and Geometry, Cambridge.
A. A. Common, Esq., LL.D., F.R.S.
A. M. W. Downing, Esq., M.A., D.Sc. F.R.S., Superintendent of the *Nautical Almanac*.
Major E. H. Hills, R.E.
Thomas Lewis, Esq.
Frank McClean, Esq., M.A., LL.D., F.R.S.
Major P. A. MacMahon, D.Sc., F.R.S.
A. A. Rambaut, Esq., D.Sc., F.R.S., Radcliffe Observer.
G. M. Seabroke, Esq.
E. J. Spitta, Esq.
W. G. Thackeray, Esq.
H. H. Turner, Esq., D.Sc., F.R.S., Savilian Professor of Astronomy, Oxford.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXII. MARCH 14, 1902. No. 5

Dr. J. W. GLAISHER, M.A., F.R.S., President, in the Chair.

John Walter Lawrence Child, Vernham, Merton Hall Road, Wimbledon;
José Comas Solá, S. Felipe, 29 S. Gervasio, Barcelona, Spain;
Rev. John Horsley Haslam, M.A., Vicar of St. Saviour's, Denmark Park, S.E.;
Joseph Lunt, B.Sc., F.I.C., Royal Observatory, Cape of Good Hope; and
Joges Chandra Ray, M.A., Professor of Physical Science, Cuttack, Bengal, India,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Alexander Eugen Conrady, F.R.M.S., 104 Park Street, Camden Town, N.W. (proposed by Edmund J. Spitta);
Henry Tresawna Gerrans, M.A., Fellow and Tutor of Worcester College, Oxford (proposed by Arthur R. Rambaut); and
Maurice Edmond Joseph Gheury, 23 Downshire Hill, Hampstead, N.W. (proposed by Silvanus P. Thompson).

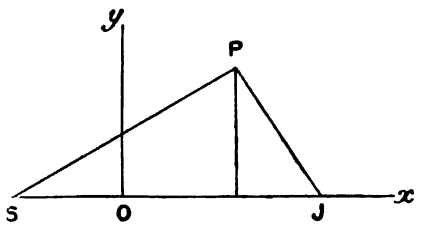
One hundred and ten presents were announced as having been received since the last meeting, including, amongst others :—

A. Auwers, Mittlere Örter von 570 Sternen aus den auf der Sternwarte Greenwich unter Direction von Pond in den Jahren 1811–1819 angestellten Beobachtungen abgeleitet (presented by the author) ; Professional papers of the Survey of India Department, No. 5, containing Major S. G. Burrard's paper on the attraction of the Himalaya Mountains (presented by the Survey Department).

On Perodic Orbits in the Restricted Problem of Three Bodies.
By E. T. Whittaker, M.A.

1. *Introduction.*—In a paper published in the *Monthly Notices*, vol. lxii. pp. 186–193, two properties of periodic orbits were communicated. The periodic orbits discussed in that paper were the closed curves which can be described by a body moving under the influence of any number of centres of force. It was supposed that these centres of force are fixed, so that the energy of the body can be partitioned into kinetic energy, which is a homogeneous quadratic function of the components of velocity, and potential energy, which does not involve the components of velocity or the time at all.

The application of periodic orbits, which is most important from the astronomical point of view, is the application to the restricted problem of three bodies (the orbits of Hill, Poincaré, and Darwin). This problem consists in the determination of the motion of a small planet P under the attraction of the Sun S and a large planet J, it being assumed that the motion of S and J is purely circular, and that the whole motion takes place in one plane. In this problem the conditions are not so simple as in the class of problems studied in the previous paper, since S and J are not fixed but *moving* centres of force, and the theorems here stated cannot be applied.



The object of the present note is to show that the methods of the previous paper can nevertheless be extended to the restricted problem of three bodies, and that two results can thus be

obtained which are analogous to, though differing from, those given in the previous paper.

2. *Formation of the equation of least Action.*—Of the attracting bodies let S be of mass m_1, and J of mass m_2. Let O be their centre of gravity, which we can regard as fixed. Let x and y be the co-ordinates of P, when the point O is taken as origin, with the moving line OJ as axis of x, and a line perpendicular to it as axis of y. Let x be the angular velocity of OJ, and let

$$\mathrm{F}(x, y) = \frac{m_1}{\mathrm{SP}} + \frac{m_2}{\mathrm{JP}}.$$

Then the differential equations of motion of the problem are

$$\begin{cases} \dfrac{d}{dt}\left(\dfrac{\partial \mathrm{L}}{\partial \dot{x}}\right) - \dfrac{\partial \mathrm{L}}{\partial x} = 0 \\ \dfrac{d}{dt}\left(\dfrac{\partial \mathrm{L}}{\partial \dot{y}}\right) - \dfrac{\partial \mathrm{L}}{\partial y} = 0, \end{cases}$$

where the Lagrangian function L is given by the equation

$$\mathrm{L} = \tfrac{1}{2}\{(\dot{x} - ny)^2 + (\dot{y} + nx)^2\} + \mathrm{F}(x, y),$$

and $\dot{x}$, $\dot{y}$ denote $\dfrac{dx}{dt}$, $\dfrac{dy}{dt}$ respectively.

The corresponding integral of energy is

$$\tfrac{1}{2}(\dot{x}^2 + \dot{y}^2) - \frac{n^2}{2}(x^2 + y^2) - \mathrm{F}(x, y) = h,$$

where h is the constant of energy.

Now write,

$$y' = \frac{dy}{dx} = \frac{\dot{y}}{\dot{x}},$$

and write

$$\Omega = \tfrac{1}{2}\{(\dot{x} - ny)^2 + (y'\dot{x} + nx)^2\} + \mathrm{F}(x, y),$$

so that it is equal to L, but is expressed differently,

Now the integral of energy can be written

$$\dot{x}\frac{\partial \Omega}{\partial \dot{x}} - \Omega = h,$$

and this equation can be regarded as giving $\dot{x}$ in terms of x, y, y', and h. Differentiating it on this supposition, we have

$$\dot{x}\frac{\partial^2 \Omega}{\partial \dot{x}^2}\frac{\partial \dot{x}}{\partial y'} + \dot{x}\frac{\partial^2 \Omega}{\partial \dot{x} \partial y'} - \frac{\partial \Omega}{\partial y'} = 0$$

and

$$\dot{x}\frac{\partial^2 \Omega}{\partial \dot{x}^2}\frac{\partial \dot{x}}{\partial y} + \dot{x}\frac{\partial^2 \Omega}{\partial \dot{x} \partial y} - \frac{\partial \Omega}{\partial y} = 0.$$

Now let $L' = \frac{\partial \Omega}{\partial \dot{x}}$, where L′ is supposed expressed in terms of x, y, and y', so that

$$L' = n(xy' - y) + (1 + y'^2)^{\frac{1}{2}} \{n^2(x^2 + y^2) + 2F(x, y) + 2h\}^{\frac{1}{2}}.$$

Then the two last equations become

$$\dot{x}\frac{\partial L'}{\partial y'} - \frac{\partial \Omega}{\partial y'} = 0$$

and

$$\dot{x}\frac{\partial L'}{\partial y} - \frac{\partial \Omega}{\partial y} = 0,$$

or

$$\frac{\partial L'}{\partial y'} = \frac{\partial L}{\partial \dot{y}}$$

and

$$\frac{\partial L'}{\partial y} = \frac{1}{\dot{x}}\frac{\partial L}{\partial y}.$$

The equation

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{y}}\right) - \frac{\partial L}{\partial y} = 0$$

becomes therefore

$$\frac{d}{dx}\left(\frac{\partial L'}{\partial y'}\right) - \frac{\partial L'}{\partial y} = 0,$$

and this single equation, which connects y and x and does not involve t, is the differential equation of those orbits for which the constant of energy is h.

To this equation there corresponds a statement of the principle of least action, namely that the integral

$$\int L' dx$$

has a value which is stationary for the actual trajectory between two given terminal points, as compared with neighbouring curves joining the same two terminal points.

3. *A criterion for the discovery of periodic orbits.*—Now consider any simple closed curve in the plane of xy; and let another simple closed curve C′ be drawn, enclosing C and differing only slightly from it. We may regard C′ as defined by an equation of the form

$$\delta p = \text{a function of } \phi,$$

where δp is the normal distance between the curves C and C′, and ϕ is the inclination of this normal distance to the axis of x.

Then if I be the value of the integral

$$\int L' dx$$

when the integration is taken round the curve C, and if $I+\delta I$ denote the value of the same integral when the integration is taken round the curve C′ (so that the symbol δ denotes an increment obtained in passing from C to C′), we find, by a method similar to that used in the previous paper, that

$$\delta I = \int \delta p \, . \, K \, . \, \{(dx)^2+(dy)^2\}^{\frac{1}{2}},$$

where, writing

$$\{h+F(x, y)+\tfrac{1}{2}n^2(x^2+y^2)\}^{\frac{1}{2}} = G(x, y),$$

we have

$$K = \frac{G(x,y)}{\varphi} + \cos\phi \frac{\partial G(x,y)}{\partial x} + \sin\phi \frac{\partial G(x,y)}{\partial y} + \frac{n}{\sqrt{2}}.$$

This equation shows that if the quantity K is positive at all points of C, then δI is positive, and, so the quantity I has its value increased when any curve surrounding C and adjacent to C is taken instead of C as the path of integration.

Now, suppose that another simple closed curve D can be drawn enclosing C, and such that at all points of D the quantity K is negative. Then in the same way it can be shown that the quantity I is increased when any simple closed curve D′, enclosed by D and adjacent to D, is taken instead of D as the path of integration.

It follows, therefore, by reasoning similar to that used in the previous paper, that, among the aggregate of simple closed curves situated in the ring-shaped space bounded by C and D, there exists a curve L, for which the value of the integral I is greater than for all the other curves of the aggregate. The curve L thus furnishes a stationary value of the integral of least action, and so is an orbit in the restricted problem of three bodies. We thus obtain theorem

If one closed curve be enclosed by another closed curve, and if the quantity K *be positive at all points of the inner curve and negative at all points of the outer curve, then in the ring-shaped space between the two curves there exists a periodic orbit of the restricted problem of three bodies, having the given arbitrary constant h as its constant of energy.*

As the quantity K can be immediately calculated for every point on any given curve, this result furnishes a means of detecting the presence of periodic orbits. It may be regarded as analogous to those methods of finding the position of roots of an algebraic equation, which depend on considerations relating to the sign of some expressions connected with the equation.

4. *An integral connected with the periodic orbits.*—Consider now the integral

$$\frac{1}{2\pi}\iint\left[\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\log\{h+F(x, y)+\tfrac{1}{2}n^2(x^2+y^2)\}\right] dxdy,$$

where the integration is taken over the interior of any periodic orbit C in the restricted problem of three bodies. As the integrand is infinite at the points S and J we shall first suppose that, if S and J are in the interior of the orbit, small circles γ and γ' are drawn around them. If S and J are not enclosed by the periodic orbit the circles γ and γ' will be non-existent; but in order to secure the greatest generality we shall assume that they exist.

Then, if S denote the region which is contained within C but is exterior to γ and γ', we have (by Green's theorem on the conversion of integrals taken over an area into integrals taken round the boundary of the area) the equality

$$\frac{1}{2\pi}\iint_{S}\left[\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\log\{h+F(x,y)+\tfrac{1}{2}n^2(x^2+y^2)\}\right]dxdy$$

$$=\frac{1}{2\pi}\left[\iint_{C}-\int_{\gamma}-\int_{\gamma'}\right]\begin{vmatrix} dy\,\dfrac{\partial}{\partial x}\log\{h+F(x,y)+\tfrac{1}{2}n^2(x^2+y^2)\} \\ -dx\,\dfrac{\partial}{\partial y}\log\{h+F(x,y)+\tfrac{1}{2}n^2(x^2+y^2)\}\end{vmatrix}$$

the integrals round γ and γ' being inserted only when γ and γ' exist.

But the integral previously denoted by δI must be zero when the integration is taken along an arc of an actual orbit; and this (since the quantity δp which occurs in δI is arbitrary) shows that the equation

$$K=0$$

or $$\frac{1}{\rho}+\cos\phi\frac{\partial\log G(x,y)}{\partial x}+\sin\phi\frac{\partial\log G(x,y)}{\partial y}+\frac{n}{\sqrt{2}G(x,y)}=0$$

is satisfied at every point of the orbit; that is, the equation

$$2\{dx^2+dy^2\}^{-\frac{1}{2}}d\phi+\left(\cos\phi\frac{\partial}{\partial x}+\sin\phi\frac{\partial}{\partial y}\right)\log\{h+F(x,y)$$

$$+\tfrac{1}{2}n^2(x^2+y^2)\}+\sqrt{2}n\{h+F(x,y)+\tfrac{1}{2}n^2(x^2+y^2)\}^{\frac{1}{2}}=0$$

or

$$2d\phi+dy\frac{\partial}{\partial x}\log\{h+F(x,y)+\tfrac{1}{2}n^2(x^2+y^2)\}$$

$$-dx\,.\,\frac{\partial}{\partial y}\log\{h+F(x,y)+\tfrac{1}{2}n^2(x^2+y^2)\}+2n\,dt=0$$

is satisfied at every point of the curve C. We have therefore

$$\frac{1}{2\pi}\int_C \left(dy\frac{\partial}{\partial x}-dx\frac{\partial}{\partial y}\right)\log\{h+F(x,y)+\tfrac{1}{2}n^2(x^2+y^2)\}$$

$$=-\frac{1}{2\pi}\int_C (2d\phi+2ndt)$$

$$=-2-\frac{\Gamma}{\pi},$$

where Γ is the angle through which the whole system of S, J, and P has turned in space during one period of the periodic orbit.

We have next to consider the integrals which arise from the curves γ and γ'. We shall take first the integral arising from the curve γ. We shall suppose that the centre of γ is at S, and that its radius is a small quantity f.

Then in the neighbourhood of S we have

$$h+F(x,y)+\frac{n^2}{2}(x^2+y^2)=\frac{m_1}{SP}+\text{terms finite in the neighbourhood};$$

thus
$$\left(dy\frac{\partial}{\partial x}-dx\frac{\partial}{\partial y}\right)\log\left\{h+F(x,y)+\frac{n^2}{2}(x^2+y^2)\right\}$$
$$=-dy\frac{OS+x}{SP^2}+dx\,.\,\frac{y}{SP^2}+\text{less important terms.}$$

Therefore

$$-\frac{1}{2\pi}\int_\gamma \left(dy\frac{\partial}{\partial x}-dx\frac{\partial}{\partial y}\right)\log\left\{h+F(x,y)+\frac{n^2}{2}(x^2+y^2)\right\}$$

$$=\frac{1}{2\pi\rho^2}\int_\gamma\{(OS+x)dy-ydx\}+\text{infinitesimal terms}$$

$$=\frac{1}{2\pi\rho^2}\times\text{twice the area of }\gamma$$

$$=1.$$

Similarly the integral arising from γ' has the value unity.

This result is clearly independent of the radius of the small circles γ and γ', provided these are infinitesimal; we are thus entitled to speak of the integral of the quantity

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\log\left\{h+F(x,y)+\frac{n^2}{2}(x^2+y^2)\right\}$$

taken over the interior of the periodic orbit, since the arbitrary

element of choice in the circles γ and γ' does not affect the value of the integral. We thus obtain the result—

The integral

$$\frac{1}{2\pi}\iint\left[\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\log\{h+F(x,y)+\tfrac{1}{2}n^2(x^2+y^2)\}\,dxdy,\right.$$

where the integration is taken over the interior of any periodic orbit in the restricted problem of three bodies, has the value

$$-\frac{\Gamma}{\pi},\text{ or }-1-\frac{\Gamma}{\pi},\text{ or }-2-\frac{\Gamma}{\pi},$$

according as the periodic orbit encloses both, one, or none of the bodies S *and* J*; where* Γ *is the angle through which the whole system composed of* S, J, *and* P *turns in space during one period of the periodic orbit.*

1902 *January* 24.

On the Images formed by a Parabolic Mirror. First Paper: The Geometrical Theory. By H. C. Plummer, M.A.

1. *Introduction.*—As is well known the staple work of the University Observatory at Oxford during the past few years has been the execution of its share of the Astrographic Chart. At the same time lines of investigation suggested by this work have not been neglected, and much has been done in the discussion of the systematic errors to which photographs are liable. As an example of such researches reference may be made to Professor Turner's papers on the optical distortion of the photographic doublet (*Monthly Notices*, vol. lix. p. 438).

Soon after I became associated as assistant with the observatory Professor Turner suggested that, as I had already paid some attention to the forms of the images produced by a reflecting telescope (*A. J.*, No. 435) I should extend and as far as possible complete this study. Accordingly I undertook the direct comparison of a plate kindly lent by Dr. Isaac Roberts with one of our own astrographic plates. This task is proceeding and will, I hope, shortly be finished. In the meantime a comparison of my own carlier paper with various other theoretical papers revealed apparent discrepancies which it is desirable to remove by a thorough revision of this part of the subject. The results of this investigation are independent of the actual comparison of the two plates, and it seems convenient therefore to publish them separately.

2. My earlier paper, "On the Star Image formed by a Parabolic Mirror," was published in the *Astronomical Journal*,

No. 435, simultaneously with one by Mr. J. M. Schaeberle. Previously, in 1887, the subject had been discussed by General Tennant (*Monthly Notices*, vol. xlvii. p. 244). A fourth paper, by Mr. C. W. Crockett (*Astrophysical Journal*, vol. vii. p. 362), will also receive notice. Curiously enough the first two and the last of these papers all bear the date 1898 March. Differences of notation and variety of method have made it necessary to collate these papers with considerable care. The outcome of the examination may be briefly indicated here. In General Tennant's paper an unfortunate slip is pointed out which seems to have escaped detection hitherto, and which makes his final results only an approximation to the truth. I have found that Mr. Schaeberle's formulæ are right, though left in a rather inconvenient form, if we correct an apparent misprint. On the other hand his figures of the image formed by different zones of the mirror are certainly incorrect in detail. In Mr. Crockett's results, so far as they go, there is nothing calling for criticism; on the contrary, I have found his curves, evidently drawn with great care, most interesting. In my own paper rigorous expressions were found for the equations of the reflected ray. The further development of the theory was based on a clearly defined approximation which led in a remarkably simple manner to results sufficiently in accord with the actual appearance of star images. The degree of approximation adopted is easily examined, but no examination was made before and the omission will be rectified in the present paper. The analysis will also be extended so as to consider the form of the image in a plane close to, but not coincident with, the focal plane, a step which has not hitherto been taken in any paper, so far as I am aware.

3. *General Theory.*—I retain as far as possible the notation of my previous paper. Let the equation of the surface of the mirror be

$$4fx = y^2 + z^2 = r^2.$$

Let the plane ZOX be the principal plane, *i.e.* the plane containing the axis of the mirror and the ray incident at O, the vertex, and let θ be the angular distance of the star from the centre of the field, being in the positive direction from OX. The direction cosines of the normal at P, the point of incidence (x, y, z), are

$$\frac{2f}{\sqrt{4f^2+r^2}}, \quad \frac{-y}{\sqrt{4f^2+r^2}}, \quad \frac{-z}{\sqrt{4f^2+r^2}}.$$

We may then put

$$\cdots \qquad \cdots r = 2f \tan \tfrac{1}{2}v, \; y = r \sin \phi, \; z = r \cos \phi.$$

If F is the focus, v is the angle OFP and ϕ is the angle

between the planes POX and ZOX. The direction cosines of the normal become

$$+\cos\tfrac{1}{2}v, \quad -\sin\tfrac{1}{2}v\sin\phi, \quad -\sin\tfrac{1}{2}v\cos\phi.$$

If χ is the angle between the incident ray and the normal we have

$$\cos\chi = \cos\tfrac{1}{2}v\cos\theta - \sin\tfrac{1}{2}v\cos\phi\sin\theta$$

Let (λ, μ, ν) be the direction cosines of the reflected ray. Now the direction cosines of the incident and reflected rays may also be regarded as the coordinates of points at unit distance from O along lines parallel to those rays. And the direction cosines of the normal multiplied by cos χ are the coordinates of a point at a distance cos χ from O along a line parallel to the normal. But this point is clearly midway between the other two, and by expressing this fact we obtain

$$\begin{aligned}
\lambda + \cos\theta &= 2\cos\tfrac{1}{2}v\left[\cos\tfrac{1}{2}v\cos\theta - \sin\tfrac{1}{2}v\cos\phi\sin\theta\right]\\
\mu &= -2\sin\tfrac{1}{2}v\sin\phi\left[\cos\tfrac{1}{2}v\cos\theta - \sin\tfrac{1}{2}v\cos\phi\sin\theta\right]\\
\nu + \sin\theta &= -2\sin\tfrac{1}{2}v\cos\phi\left[\cos\tfrac{1}{2}v\cos\theta - \sin\tfrac{1}{2}v\cos\phi\sin\theta\right].
\end{aligned}$$

Hence

$$\left.\begin{aligned}
\lambda &= \cos v\cos\theta - \sin v\sin\theta\cos\phi\\
\mu &= -\sin v\cos\theta\sin\phi + \sin^2\tfrac{1}{2}v\sin\theta\sin 2\phi\\
\nu &= -\sin v\cos\theta\cos\phi + \sin^2\tfrac{1}{2}v\sin\theta\cos 2\phi - \cos^2\tfrac{1}{2}v\sin\theta
\end{aligned}\right\} \quad (1)$$

4. Now let the reflected ray, whose direction cosines have just been found, meet the focal plane in the point (ξ, η, ζ). Then,

$$\xi = f, \qquad \eta = y + \frac{\mu}{\lambda}(f-x), \qquad \zeta = z + \frac{\nu}{\lambda}(f-x).$$

Remembering that

$$f - x = f(1 - \tan^2\tfrac{1}{2}v) = f\cos v\sec^2\tfrac{1}{2}v;$$

we then find

$$\begin{aligned}
\lambda\eta &= 2f\tan\tfrac{1}{2}v\sin\phi\,(\cos v\cos\theta - \sin v\sin\theta\cos\phi)\\
&\quad + f\cos v\sec^2\tfrac{1}{2}v\,(-\sin v\cos\theta\sin\phi + \sin^2\tfrac{1}{2}v\sin\theta\sin 2\phi)\\
&= -f\tan^2\tfrac{1}{2}v\sin\theta\sin 2\phi.
\end{aligned}$$

$$\begin{aligned}
\lambda\zeta &= 2f\tan\tfrac{1}{2}v\cos\phi\,(\cos v\cos\theta - \sin v\sin\theta\cos\phi)\\
&\quad + f\cos v\sec^2\tfrac{1}{2}v\,(-\sin v\cos\theta\cos\phi + \sin^2\tfrac{1}{2}v\sin\theta\cos 2\phi\\
&\qquad - \cos^2\tfrac{1}{2}v\sin\theta) = -f\tan^2\tfrac{1}{2}v\sin\theta\cos 2\phi - f\sin\theta.
\end{aligned}$$

The co-ordinates may therefore be written in the form

$$\left.\begin{aligned}
\eta &= -\frac{f\tan\theta}{\cos v}\cdot\frac{\tan^2\tfrac{1}{2}v\sin 2\phi}{1 - \tan v\tan\theta\cos\phi}\\
\zeta &= -\frac{f\tan\theta}{\cos v}\cdot\frac{1 + \tan^2\tfrac{1}{2}v\cos 2\phi}{1 - \tan v\tan\theta\cos\phi}
\end{aligned}\right\} \quad \ldots \quad \ldots \quad (2)$$

These simple expressions make a very convenient basis for a study of the aberration in the focal plane of a parabolic mirror.

5. Let us now put

$$d = -f \tan\theta \sec v, \qquad a = \tan^2 \tfrac{1}{2}v, \qquad b = \tan v \tan\theta.$$

Then the equations found for the co-ordinates may be written

$$\left.\begin{aligned} \frac{\eta}{d} &= \frac{a \sin 2\phi}{1 - b\cos\phi} \\ \frac{\zeta}{d} &= \frac{1 + a\cos 2\phi}{1 - b\cos\varphi} \end{aligned}\right\} \quad \ldots \quad \ldots \quad \ldots \quad (3).$$

and these may be regarded as equations in terms of a third variable ϕ of the geometrical image formed in the focal plane by a circular zone of the mirror. They are in the form most convenient for the discussion of the properties of the curve which they represent, and make it easy to plot the curve for any assigned values of the constants. It is merely of mathematical interest to eliminate ϕ and so obtain the ordinary Cartesian equation. It is convenient first to move the origin from the centre of the field along the axis of ζ to the point $\zeta = d(1-a)$. When this is done the result of elimination is :

$$\begin{aligned} &(\eta^2+\zeta^2)[\eta^2\{(1-a)b^2+2a\}^2+4a^2(1-b^2)\zeta^2] \\ &\quad + 2d\zeta[\eta^2\{b^2(1-a)^2(b^2\overline{1-a}+2a)+2a\mathrm{J}\} - 4a^2\zeta^2(b^2\overline{1-a}+2a)] \\ &\quad + d^2\mathrm{J}\{b^2(1-a)^2\eta^2 - 4a^2\zeta^2\} = 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4) \end{aligned}$$

where

$$\mathrm{J} = b^2(1-a)^2 - 4a^2.$$

The curve is therefore a quartic.

6. We can now draw from (2) some simple inferences with regard to the properties of the curves formed by the rays reflected at a circular ring of the mirror. In the first place we see, by changing the sign of ϕ, that the curve is symmetrical about a radius through the centre of the field, a fact which is obvious *a priori* and from the form of equation (4). On the trace of the principal plane or axis of symmetry we have the following scheme of values :—

$$\phi = 0, \quad \eta = 0, \quad \zeta = -f\frac{\tan\theta \cdot \sec v \sec^2\frac{1}{2}v}{1 - \tan v \tan\theta} = d \cdot \frac{1+a}{1-b} \ldots \quad (\mathrm{A})$$

$$\phi = \frac{\pi}{2}, \quad \eta = 0, \quad \zeta = -f\tan\theta \cdot \sec^2\tfrac{1}{2}v = d(1-a) \quad \ldots \quad (\mathrm{B})$$

$$\phi = \pi, \quad \eta = 0, \quad \zeta = -f\frac{\tan\theta \cdot \sec v \sec^2\frac{1}{2}v}{1 + \tan v \tan\theta} = d \cdot \frac{1+a}{1+b} \ldots \quad (\mathrm{C})$$

$$\phi = \frac{3\pi}{2}, \quad \eta = 0, \quad \zeta = -f\tan\theta \cdot \sec^2\tfrac{1}{2}v = d(1-a) \quad \ldots \quad (\mathrm{B})$$

It may be remarked that investigations confined to the principal plane are quite inadequate, inasmuch as they fail to explain the genesis of the image in the principal plane itself. The point B is clearly a double point lying on the two branches of the curve which correspond to $\phi=\frac{\pi}{2}$ and $\phi=\frac{3\pi}{2}$. This also is shown by the Cartesian equation, which gives for the tangents at the point

$$\left.\begin{array}{l} b(1-a)\eta \pm 2a\zeta=0 \\ \text{or} \quad \tan\theta\,.\,\eta \pm \tan\tfrac{1}{2}v\,.\,\zeta=0 \end{array}\right\} \quad \ldots \quad \ldots \quad (5)$$

This would indicate that the tangents are equally inclined to the axes when $v=2\theta$. It will be noticed, however, that J, the numerical coefficient of the terms of the lowest degree, vanishes at the same time. It is necessary to observe therefore that the terms of the third degree possess the terms of lowest degree as a factor when the coefficient vanishes, and continuity is thus preserved. I have purposely thrown the terms of the third degree into a form which reveals this fact on inspection. Thus when $v=2\theta$ there is a triple point through which pass the branches corresponding to $\phi=\frac{\pi}{2}, \phi=\pi$, and $\phi=\frac{3\pi}{2}$. When $v>2\theta$, the points BC A are in order of increasing distance from the centre of the field and from the point I corresponding to the ray reflected at the vertex of the mirror.

7. It is important now to examine the maximum and minimum values of the coordinates. For a critical value of η

$$2\cos 2\phi\,(1-\tan v\tan\theta\cos\phi)=\tan v\tan\theta\sin\phi\sin 2\phi$$

$$\therefore\ 2\cos 2\phi-\tan v\tan\theta\cos 2\phi\cos\phi=\tan v\tan\theta\cos\phi$$

$$\therefore\ \cos 2\phi=\tan v\tan\theta\cos^3\phi \quad \ldots \quad \ldots \quad (6)$$

Now $\tan v\tan\theta=b$ is always small in a practical case. To take an extreme instance, one of Dr. Common's mirrors has a focal length of 3·7 feet and an aperture of 1·7 feet. For the outside ring $v=13°$, and if $\theta=2\frac{1}{2}°$ b only amounts to ·01. Hence we are justified in taking $\phi=\frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}$ or $\frac{7\pi}{4}$ as the solution of (6), though a closer approximation to the roots can easily be made if desired. The points where η is a maximum or minimum are therefore given by

$$\phi=\frac{\pi}{4} \text{ or } \frac{7\pi}{4},\ \eta=\pm d\,.\,\frac{a}{1-b/\sqrt{2}},\ \zeta=d\,.\,\frac{1}{1-b/\sqrt{2}} \quad \ldots \quad (\text{E, E}')$$

$$\phi=\frac{3\pi}{4} \text{ or } \frac{5\pi}{4},\ \eta=\pm d\,.\,\frac{a}{1+b/\sqrt{2}},\ \zeta=d\,.\,\frac{1}{1+b/\sqrt{2}} \quad \ldots \quad (\text{D, D}')$$

Since b is small the width of the curve at the points where ζ has these two values is practically the same, viz. $2ad$.

Again, for a critical value of ζ,

$$-2\tan^2\tfrac{1}{2}v\sin 2\phi\,(1-\tan v\tan\theta\cos\phi)$$
$$=\tan v\tan\theta\sin\phi\,(1+\tan^2\tfrac{1}{2}v\cos 2\phi)\quad\ldots\quad\ldots\quad\ldots\quad(7)$$

This is satisfied by $\sin\phi=0$, *i.e.* $\phi=0$ or π. The curve at the points A and C crosses the axis of ζ at right angles. The factor $\sin\phi$ being omitted, the equation reduces to

$$2\tan^2\tfrac{1}{2}v\tan v\tan\theta\cos^2\phi-4\tan^2\tfrac{1}{2}v\cos\phi$$
$$-\tan v\tan\theta\,(1-\tan^2\tfrac{1}{2}v)=0$$

or
$$2ab\cos^2\phi-4a\cos\phi-b\,(1-a)=0$$
$$\therefore\ 2ab\cos\phi=2a\pm\sqrt{[4a^2+2a(1-a)b^2]}$$
$$\therefore\ 2ab\cos\phi=2a\pm[2a+\tfrac{1}{2}b^2(1-a)-\ldots]$$

The upper sign is impossible, for it would make $\cos\phi>1$. The lower sign, if higher powers of b be neglected, gives

$$\cos\phi=-b\,(1-a)/4a=-\tan\theta/2\tan\tfrac{1}{2}v.$$
$$\therefore\phi=\pi\pm\cos^{-1}\frac{\tan\theta}{2\tan\tfrac{1}{2}v}\quad\ldots\quad(\mathrm{H},\mathrm{H}')$$

8. These values of ϕ give minimum values of ζ which become impossible when v is small, the limit occurring when $v=\theta$ approximately. After the disappearance of these minima as the centre of the mirror is approached the true minimum is given by $\phi=\pi$. It is then theoretically important to determine v so as to make ζ an absolute minimum. Now

$$\zeta=-f\tan\theta\frac{\sec^2\tfrac{1}{2}v}{\cos v+\sin v\tan\theta}$$

Hence for a minimum

$$\sec^2\tfrac{1}{2}v\tan\tfrac{1}{2}v(\cos v+\sin v\tan\theta)=\sec^2\tfrac{1}{2}v(-\sin v+\cos v\tan\theta)$$
$$\therefore\tan\tfrac{1}{2}v(1-\tan^2\tfrac{1}{2}v+2\tan\tfrac{1}{2}v\tan\theta)+2\tan\tfrac{1}{2}v$$
$$-(1-\tan^2\tfrac{1}{2}v)\tan\theta=0$$
$$\therefore\tan\theta=\frac{3\tan\tfrac{1}{2}v-\tan^3\tfrac{1}{2}v}{1-3\tan^2\tfrac{1}{2}v}=\tan\tfrac{3}{2}v$$
$$\therefore v=\tfrac{2}{3}\theta.$$

This value of v leads to

$$\zeta=-f\sin\theta\sec^3\tfrac{1}{3}\theta.$$

Also it is easy to see that the maximum value of ζ corresponds to $\phi=0$ and is by (A)

$$\zeta=-f\sin\theta\,.\,\sec^2\tfrac{1}{2}v\sec(v+\theta),$$

which again is greatest when v corresponds to the edge of the mirror. The total length of the complete geometrical image is therefore

$$l=f\sin\theta\,[\sec^2\tfrac{1}{2}v\sec(v+\theta)-\sec^3\tfrac{1}{3}\theta]\quad\ldots\quad(8)$$

and if powers and products of v and θ of the fifth order be neglected the expression obtained becomes

$$l = \tfrac{1}{12} f\theta(3v+2\theta)^2.$$

But this expression is of purely theoretical interest and does not apply strictly to a reflector as adapted for photographic use, since the central part of the mirror is cut off by the plate-holder and thus a part of the image is lost (*see* §15).

9. *On General Tennant's Paper* (*Monthly Notices*, vol. xlvii. p. 244).—I follow here General Tennant's own notation. He writes down (p. 250) the equations of the reflected ray thus: in the plane XY_0

$$y_0 - av = \frac{4c-4v-cv^2}{4+4cv-v^2}\left(x-\frac{av^2}{4}\right)$$

and in the plane XZ_0

$$Z_0 = \left(\frac{av^2}{4}-x\right)\tan a \sin \phi.$$

I say that the latter equation is incorrect. Simple geometrical considerations would show that this is so, but perhaps the most satisfactory method will be to find the right equation which ought to be substituted for the preceding.

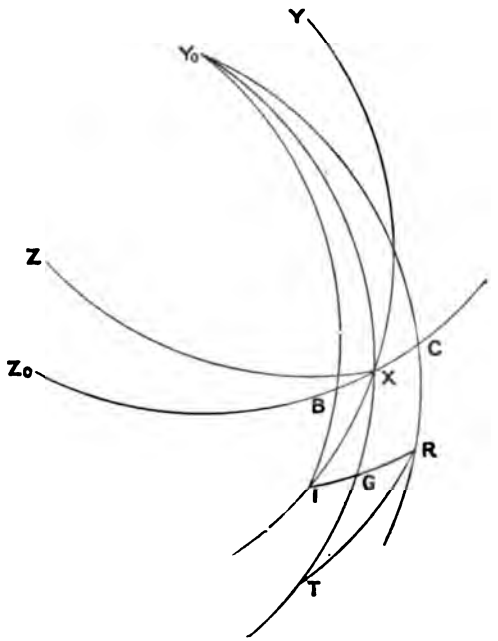


FIG. 1.

Now the point of incidence P_1 of the ray on the mirror is $(\frac{1}{4}av^2, av, 0)$, the axes being $X_0\ Y_0\ Z_0$. If then $v = 2\tan\psi$, ψ is the angle between the axis of the mirror and the normal at P_1. We are chiefly concerned with the directions of certain lines, and we therefore construct a spherical figure (fig. 1) by drawing parallels through the centre of a sphere. Let X Y Z, X Y_0 Z_0 correspond to the two sets of axes and I, G, R to the incident ray, the normal and the reflected ray respectively. We notice that YXI, Y_0XG, and IGR lie on the same great circles and that IG = GR. Let Y_0I and Y_0R cut Z_0X in B and C, and let $BX = BY_0X = \beta$ and $XC = XY_0C = \gamma$. The points B and C correspond to the projections of the incident and reflected rays on the plane XZ_0. Hence the equations of these projections are :

$$z_0 = (x - \tfrac{1}{4}av^2)\tan\beta$$
$$z_0 = (\tfrac{1}{4}av^2 - x)\tan\gamma.$$

On Y_0G produced we take T so that $GT = XG = \psi$. Then the triangles XGI, TGR are altogether equal, and consequently $RT = IX = \alpha$ and $GTR = GXI = YXY_0 = \phi$. Hence from the triangle Y_0TR, in which $Y_0T = \frac{\pi}{2} + 2\psi$ we get

$$-\sin 2\psi \cos\phi = \cos 2\psi \cot\alpha - \sin\phi \cot\gamma.$$

And from the triangle Y_0XI

$$0 = \cot\alpha - \sin\phi \cot\beta.$$

We have then

$$\tan\beta = \sin\phi \tan\alpha$$

and

$$\tan\gamma = \frac{\sin\phi}{\cos 2\psi \cot\alpha + \sin 2\psi \cos\phi}$$
$$= \frac{(4+v^2)\sin\phi \tan\alpha}{4 + 4cv - v^2}$$

We see then that General Tennant has in effect made the tacit assumption that $\gamma = \beta$. If we avoid this error and proceed with the transformation by means of the formulæ

$$y = y_0 \cos\phi - z_0 \sin\phi$$
$$z = y_0 \sin\phi + z_0 \cos\phi$$

we shall obtain the equations of the reflected ray in the proper form and arrive at results equivalent to those found in §§ 3 and 4. The oversight is most unfortunate, as it detracts from an otherwise admirable paper, which, so far as I am aware, contains the first serious discussion of the subject under consideration.

10. *On Mr. Schaeberle's Paper* (*A. J.* No. 435).—Mr. Schaeberle's paper is based on a very elementary geometrical method which does not, however, tend to simplify the results. His

notation is retained in this review of his theory. The principal formulæ are

$$\frac{x}{F}=\sec^3\tfrac{1}{2}v\left[\sin\tfrac{1}{2}v\cos A+\frac{\cos v\sin\tfrac{1}{2}\phi\cos(180°+A+B)}{\sin(I-\tfrac{1}{2}\phi)}\right] \quad (15\,S)$$

$$\frac{y}{F}=\sec^3\tfrac{1}{2}v\left[\sin\tfrac{1}{2}v\sin A+\frac{\cos v\sin\tfrac{1}{2}\phi\sin(180°+A+B)}{\sin(I-\tfrac{1}{2}\phi)}\right] \quad (16\,S)$$

to which must be added the subsidiary relations

$$\sin B=\frac{\tan\theta\sin A}{\sqrt{[\tan^2\tfrac{1}{2}v+\tan^2\theta-2\tan\tfrac{1}{2}v\tan\theta\cos A]}} \quad \ldots\ (7\,S)$$

$$\cos I=\sin\tfrac{1}{2}v\cos B \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8\,S)$$

$$\sin\tfrac{1}{2}\phi=\sin I\cos\theta\sqrt{[\tan^2\tfrac{1}{2}v+\tan^2\theta-2\tan\tfrac{1}{2}v\tan\theta\cos A]} \quad (9\,S)$$

The numbers attached to these equations correspond to those given in Mr. Schaeberle's paper. His equation (7), however, contains under the radical the term $-2\tan v\tan\theta\cos A$, an apparent misprint which is corrected above. I shall now show that these equations, unpromising as they may appear, can be made to give simple expressions for the coordinates in the focal plane equivalent to those already found. It is merely necessary to eliminate B, I, and ϕ. We have, from (7 S),

$$\cos B=[\tan\tfrac{1}{2}v-\tan\theta\cos A]/p$$

where $$p^2=\tan^2\tfrac{1}{2}v+\tan^2\theta-2\tan\tfrac{1}{2}v\tan\theta\cos A.$$

$$\therefore\ \cos(A+B)=[\tan\tfrac{1}{2}v\cos A-\tan\theta]/p$$
$$\sin(A+B)=\tan\tfrac{1}{2}v\sin A/p.$$

Also, by (8S),

$$\cos I=[\sin\tfrac{1}{2}v\tan\tfrac{1}{2}v-\sin\tfrac{1}{2}v\tan\theta\cos A]/p$$

$$\therefore\ \sin I=q/p.$$

where $q^2=\sin^2\tfrac{1}{2}v+\tan^2\vartheta\,(1-\cos^2A\sin^2\tfrac{1}{2}v)-\sin v\tan\theta\cos A.$

Then by (9S)

$$\sin\tfrac{1}{2}\phi=\cos\theta\,.\,q$$
$$\therefore\cos^2\tfrac{1}{2}\phi=\cos^2\theta\cos^2\tfrac{1}{2}v+\sin^2\theta\cos^2A\sin^2\tfrac{1}{2}v+\sin v\sin\theta\cos\theta\cos A$$
$$\therefore\ \cos\tfrac{1}{2}\phi=\cos\theta\cos\tfrac{1}{2}v+\sin\theta\sin\tfrac{1}{2}v\cos A.$$

Hence

$$\sin(I-\tfrac{1}{2}\phi)=[\cos\theta\cos v\sec\tfrac{1}{2}v+2\sin\theta\sin\tfrac{1}{2}v\cos A]q/p$$
$$\therefore\ \frac{\sin\tfrac{1}{2}\phi}{\sin(I-\tfrac{1}{2}\phi)}=\frac{\cos\tfrac{1}{2}v\,.\,p}{\cos v(1+\tan v\tan\theta\cos A)}.$$

We can now substitute in (15 S). Thus:

$$\frac{x}{F} = \sec^3 \tfrac{1}{2}v \left[\sin \tfrac{1}{2}v \cos A - \frac{\cos \tfrac{1}{2}v \,(\tan \tfrac{1}{2}v \cos A - \tan \theta)}{1 + \tan v \tan \theta \cos A} \right]$$

$$= \frac{[\sin \tfrac{1}{2}v \tan v \tan \theta \cos^2 A + \cos \tfrac{1}{2}v \tan \theta]}{1 + \tan v \tan \theta \cos A} \sec^3 \tfrac{1}{2}v$$

$$\therefore x = \frac{F \tan \theta}{\cos v} \cdot \frac{1 + \tan^2 \tfrac{1}{2}v \cos 2A}{1 + \tan v \tan \theta \cos A}.$$

And similarly, by substituting in (16 S), we get

$$\frac{y}{F} = \sec^3 \tfrac{1}{2}v \left[\sin \tfrac{1}{2}v \sin A - \frac{\sin \tfrac{1}{2}v \cos A}{1 + \tan v \tan \theta \cos A} \right]$$

$$= \sin \tfrac{1}{2}v \tan v \tan \theta \sin A \cos A \, \frac{\sec^3 \tfrac{1}{2}v}{1 + \tan v \tan \theta \cos A}$$

$$\therefore y = \frac{F \tan \theta}{\cos v} \cdot \frac{\tan^2 \tfrac{1}{2}v \sin 2A}{1 + \tan v \tan \theta \cos A}.$$

These formulæ for x and y become identical with those given for ζ and η in (2) when it is remembered that A is the angle which I have called ϕ and that θ is reckoned positive in opposite directions by Mr. Schaeberle and myself, *i.e.* that we assume the star to be on opposite sides of the axis of the mirror.

11. But though Mr. Schaeberle may claim that his formulæ are essentially correct, the same cannot be said of the figure 2 which appears on p. 19 of his paper. He has drawn two curves for $\theta = 30'$ corresponding to the zones for which $v = 5°$ and $v = 3°$. The larger curve in particular is far from accurate. With regard to the drawing of this curve the following points may be noticed: (1) it is obviously of a degree higher than the fourth, for a straight line can be drawn to cut it in six points; (2) the two loops do not cut the axis of x at right angles, but possess singular points where they cross this axis; (3) the points for which A is 90° and 270° do not lie on the axis of x; (4) the most serious error lies in the disparity between the width of the loops, the true difference being of the order 1 in 1000. With the exception of (3) the same criticisms apply also to the smaller figure. It is impossible for me to trace the cause of these errors. Possibly the supposed misprint to which I have referred is really a slip. It seems more likely that the responsibility rests with the ambiguous signs which occur in connection with the irrational expressions left in the equations. Finally it may be that the arithmetic is at fault. I give drawings of the curves (fig. 2), which I hope will be found more satisfactory. I venture to deprecate the tendency to refer to the simple geometrical aberration of the parabolic mirror as "Schaeberlian." With all proper respect for Mr. Schaeberle's work I cannot help regarding this title as unnecessary and inappropriate.

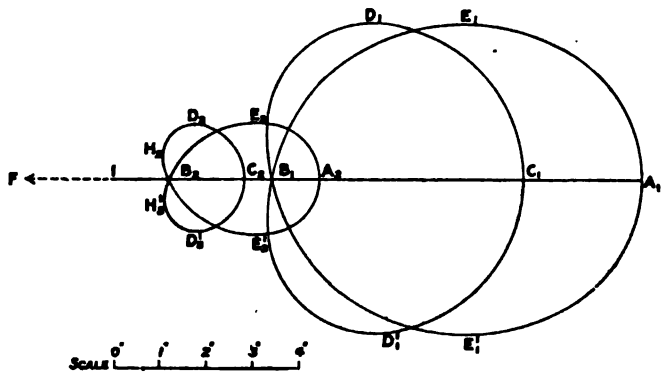


Fig. 2.

12. *On Mr. Crockett's Paper* (*Ap. J.* vii. p. 362).—I shall verify Mr. Crockett's final formulæ by deducing from them equations equivalent to (2). The set of relations marked (5) in his paper is as follows :—

$$\left.\begin{aligned} r_1 &= \frac{r \sin \alpha}{\sin (\gamma + \alpha)} \\ \cos \gamma &= \sin \theta \cos (\psi_1 - \psi) \\ \sin \gamma &= \frac{\sin (\psi_1 - \psi)}{\sin \psi} \\ \tan (\psi_1 - \psi) &= - \cos \theta \tan \psi \end{aligned}\right\} \quad \ldots \quad \ldots \quad (5\ C)$$

If I may permit myself a word of complaint I would say that the author's explanations err on the side of brevity. In the foregoing equations r, θ are the polar co-ordinates of the point of incidence in the plane containing this point and the axis of the mirror, the focus being the pole. Consequently

$$r = f \sec^2 \tfrac{1}{2}\theta.$$

Also r_1, ψ_1 are the polar co-ordinates of the corresponding point of the image in the focal plane, the focus of the mirror again being the pole. The inclination of the incident ray to the axis is α, and ψ is the same angle which I have previously denoted by ϕ. It is unnecessary to define the angle γ, since it will be eliminated immediately. Instead of the third relation we may write

$$\sin \gamma = - \cos \theta \sec \psi \cos (\psi_1 - \psi).$$

$$\therefore \sin (\gamma + \alpha) = - \sec \psi \cos (\psi_1 - \psi)$$

$$(\cos \theta \cos \alpha - \sin \theta \sin \alpha \cos \psi).$$

If then we put

$$R = -\frac{f \sec^2 \tfrac{1}{2}\theta \sin a \cos \psi}{\cos \theta \cos a - \sin \theta \sin a \cos \psi}$$

we shall have

$$\begin{aligned} x_1 = r_1 \cos \psi_1 &= R \cos \psi_1 \sec (\psi_1 - \psi) \\ &= R\{\cos \psi - \sin \psi \tan (\psi_1 - \psi)\} \\ &= R \sec \psi (\cos^2 \psi + \cos \theta \sin^2 \psi) \\ &= R \sec \psi (\cos^2 \tfrac{1}{2}\theta + \sin^2 \tfrac{1}{2}\theta \cos 2\psi) \end{aligned}$$

and

$$\begin{aligned} y_1 = r_1 \sin \psi_1 &= R \sin \psi_1 \sec (\psi_1 - \psi) \\ &= R\{\sin \psi + \cos \psi \tan (\psi_1 - \psi)\} \\ &= 2R \sin \psi \sin^2 \tfrac{1}{2}\theta. \end{aligned}$$

Hence, replacing R by the expression which it denotes, we get immediately

$$x_1 = -\frac{f \tan a}{\cos \theta} \cdot \frac{1 + \tan^2 \tfrac{1}{2}\theta \cos 2\psi}{1 - \tan \theta \tan a \cos \psi}$$

$$y_1 = -\frac{f \tan a}{\cos \theta} \cdot \frac{\tan^2 \tfrac{1}{2}\theta \sin 2\psi}{1 - \tan \theta \tan a \cos \psi}$$

and these equations again, except for changes of notation, are identical with those numbered (2).

13. In figures 4 and 5 on p. 365 of his paper Mr. Crockett has given a number of curves obtained by assuming $a = 1°$ and giving θ a series of values from 0° to 3°. Most of these curves have little or no significance in a practical study of the photographic instrument (see § 15), but their variations of form are theoretically interesting and I am glad that this part of the study can be completed by a reference to Mr. Crockett's work. I only wish to point out how his curves exemplify the theory of §§ 6–8. When $\theta = 3°$ (I follow here Mr. Crockett's notation) the resulting H curve is of the same type as those of fig. 2. When $\theta = 2° = 2a$ the G curve possesses the triple point which results from the coincidence of the points B and C. As θ becomes smaller the point I have denoted by C, passing to the other side of B, approaches the true image for the central point of the mirror, and the F curve given by $\theta = 1\tfrac{1}{2}°$ has two loops on the side of C towards the centre of the field. The point C coincides with the true image when

$$\sec \theta \sec^2 \tfrac{1}{2}\theta = 1 + \tan \theta \tan a$$

or approximately,

$$1 + \tfrac{1}{4}\theta^2 = 1 - \tfrac{1}{2}\theta^2 + a\theta.$$

This gives $\theta = \frac{4}{3}a$, and in fact when $\theta = 1\tfrac{1}{3}°$ the E curve is given passing through the point image given by $\theta = 0°$. Mean-

while the loops mentioned have disappeared and the corresponding value of θ can be estimated by identifying the maximum of y_1 at the point D with the minimum of x_1 at the point H. This gives $\frac{\tan a}{2\tan\frac{1}{2}\theta} = \cos\frac{\pi}{4}$ or $\theta = \sqrt{2}\,.\,a$ approximately. With $a = 1°$, $\theta = 1°\ 24'\ 51''$, which agrees satisfactorily with Mr. Crockett's estimate of $1°\ 25'$. The complete curve for smaller values of θ consists of two loops, one of which includes the point image given by $\theta = 0°$. When $\theta = a = 1°$, a case for which the D curve is drawn by Mr. Crockett, the symmetrical pair of points H, H' where x_1 is a minimum disappear, the geometrical meaning being that at the point denoted by C the curve ceases to be concave and becomes convex to the centre of the field. Finally the point of the image nearest to the centre of the field is given by $\theta = \frac{2}{3}a = 40'$, and after this point is reached the curves arising from the inner zones of the mirror contract in size and approach the point which in a certain sense is the true geometrical image. Mr. Crockett's curves are therefore in agreement with what the general theory would lead us to expect.

14. *On my previous paper* (*Astronomical Journal, No.* 435). The coordinates of a point of the image in the focal plane are given in this form :

$$\eta = -\frac{2yz\,(f+x)\sin\theta}{(4f^2-r^2)\cos\theta - 4fz\sin\theta}$$

$$\zeta = -\frac{\sin\theta\{4f^3+2fz^2-x(y^2-z^2)\}}{(4f^2-r^2)\cos\theta - 4fz\sin\theta}$$

When x, y, and z are expressed in terms of f, v, and ϕ these become

$$\eta = -\frac{8\sin\phi\cos\phi\tan^2\frac{1}{2}v\sec^2\frac{1}{2}v}{4(1-\tan^2\frac{1}{2}v) - 8\tan\frac{1}{2}v\tan\theta\cos\phi}\,.\,f\tan\theta$$

$$= -\frac{f\tan\theta}{\cos v}\,.\,\frac{\tan^2\frac{1}{2}v\sin 2\phi}{1-\tan v\tan\theta\cos\phi}$$

and

$$\zeta = -\frac{\{4+8\tan^2\frac{1}{2}v\cos^2\phi+4\tan^4\frac{1}{2}v\cos 2\phi\}}{4(1-\tan^2\frac{1}{2}v) - 8\tan\frac{1}{2}v\tan\theta\cos\phi}\,.\,f\tan\theta$$

$$= -\frac{f\tan\theta}{\cos v}\,.\,\frac{1+\tan^2\frac{1}{2}v\cos 2\phi}{1-\tan v\tan\theta\cos\phi}\,.$$

These expressions are therefore, as stated, exact. In the further development of the theory the approximations employed were

$$\eta = -\frac{\tan\theta}{2f}\,yz$$

$$\zeta = -f\tan\theta - \frac{\tan\theta}{4f}\,(r^2+2z^2)$$

or, as we may now write them,

$$\eta = -f \tan\theta \,.\, \tan^2 \tfrac{1}{2}v \sin 2\phi \quad \ldots \quad \ldots \quad \ldots \quad (9)$$
$$\zeta = -f \tan\theta \{1 + \tan^2 \tfrac{1}{2}v \,(2 + \cos 2\phi)\}$$

Now the aberration contains terms of the order v^2. Hence it is in general perfectly justifiable to neglect terms of the order v^4, $v^3\theta$, or $v^2\theta^2$ for practical purposes. If this is done the approximation to η is seen to be adequate. On the other hand a proper approximation to ζ is

$$\zeta = -f \tan\theta \{1 + \tan^2 \tfrac{1}{2}v \,(2 + \cos 2\phi) + \tan v \tan\theta \cos\phi\} \quad (10)$$

which differs from the preceding expression for ζ by the addition of the term $-f \tan\theta \,.\, \tan v \tan\theta \cos\phi$.

15. The effect of this term is to make the curve of the zone image depart considerably from the two coincident circles previously found, unless θ is small compared with v. The maximum value of the term when $v = n°$ and $\theta = 1°$ is about n'', and of course it diminishes fairly rapidly towards the centre of the field. It introduces distortion apart from mere change of scale value. When $\phi = \frac{\pi}{2}$ or $\frac{3\pi}{2}$ the term vanishes, and when ϕ is given values differing by π, the corresponding points are equidistant from the point given by (9) and the following equation. Hence the circle which is the locus corresponding to the latter equations may be regarded as a mean between the two loops represented by (9) and (10). This affords in many cases a justification for neglecting the term when v is fairly large; and when v is small, although the form of the curve as shown in the review of Mr. Crockett's paper undergoes considerable changes, the omission has little practical effect. This is due partly to the smallness of the curves and partly to the shadow which the photographic plate and its holder cast on the mirror. In the direction $\phi = \pi$ the light is evidently intercepted at least as far as the zone $v = 2\theta$. In the plane $\phi = \frac{\pi}{2}$ and $\frac{3\pi}{2}$ the zone $v = a$ is ineffective, $2a$ being the angular width of the field covered by the plate. The result is that the curves considered do not contribute much to the image, especially in the case of stars at some distance from the edge of the plate. The images are thus deprived of the fairly sharp point directed towards the centre of the field, and the geometrical focus for the centre of the mirror will in general lie nearer the focus of the surface than any point of the image actually formed. The precise effect in actual measurement can only be determined by experiment. With the reservation now stated I still consider the analysis of the distribution of intensity in the image, developed in my former paper, fairly satisfactory as a first approximation, and it is probably not worth while to push further a purely geometrical investigation. That examination seems certainly preferable to the merely general explanations

given elsewhere and will serve at least to emphasise the necessity of paying attention to the effect of star magnitude and time of exposure in the reduction of a photograph taken with a parabolic mirror.

16. *On the form of the image in a plane parallel to the focal plane.*—Let the reflected ray meet the plane $x = f-h$ in the point (ξ, η, ζ). Then

$$\eta = y + \frac{\mu}{\lambda}(f-h-x) = \eta_0 - \frac{\mu}{\lambda}.h$$

$$\zeta = z + \frac{\nu}{\lambda}(f-h-x) = \zeta_0 - \frac{\nu}{\lambda}.h,$$

where η_0, ζ_0 are the co-ordinates of the corresponding point in the focal plane already found in § 4. Now in the coefficients of h, which are of the first order in v, we may fairly neglect terms of the third order in v and θ. This will give as sufficient approximations to (1)

$$\mu/\lambda = -\sin\phi\tan v$$
$$\nu/\lambda = -\cos\phi\tan v - \tan\theta.$$

Then, keeping a consistent degree of approximation throughout, we use for η_0, ζ_0 the forms (9) and (10) of § 14. Thus

$$\eta = -f\tan\theta\tan^2\tfrac{1}{2}v\sin 2\phi + h\tan v\sin\phi$$
$$\zeta = -f\tan\theta\{1+\tan^2\tfrac{1}{2}v(2+\cos 2\phi) + \tan v\tan\theta\cos\phi\} + h(\tan\theta + \tan v\cos\phi).$$

Moreover, as quantities depending on h multiplied by terms of the third order in v and θ have already been neglected, it is allowable to put $f' = f-h$, and write

$$\left.\begin{aligned}\eta &= -f'\tan\theta\tan^2\tfrac{1}{2}v\sin 2\phi + h\tan v\sin\phi \\ \zeta &= -f'\tan\theta\{1+\tan^2\tfrac{1}{2}v(2+\cos 2\phi)\} - (f'\tan^2\theta - h)\tan v\cos\phi\end{aligned}\right\} \quad (11)$$

which become identical, as they should, with (9) and (10) when $h=0$, and only differ from the latter by the change of scale value indicated by f' in the place of f and by the addition of the terms $h\tan v\sin\phi$ and $h\tan v\cos\phi$ to η and ζ respectively.

17. The discussion of the locus represented by (11) may fitly be combined with that of the loci represented by (9) and the following equation and by (9) and (10), for all three loci are related in an interesting way. In the first place we put

$$\rho = 2f\tan\theta\tan^2\tfrac{1}{2}v\cos\phi \quad \ldots \quad \ldots \quad (12)$$

This is the polar equation of a circle referred to a point on its circumference, or rather of a double circle arising equally from

the variation of ϕ between 0 and π and between π and 2π. Then (9) and the following equation may be written

$$\eta = -\rho \sin \phi$$
$$\zeta = -f \tan \theta \sec^2 \tfrac{1}{2}v - \rho \cos \phi,$$

which show that the final approximations of my former paper represent a circle which, as there explained, generates a kite-shaped image of angle 60° (fig. 3*a*). Now (9) and (10) differ from the equations just considered only in the addition of the term $-f \tan^2 \theta \tan v \cos \phi$ to ζ. The nature of the modification thus introduced is easily understood, and is illustrated in fig. 3*b*. It would then be possible to deduce the character of the locus represented by (11) from the locus last considered by changing f into f' in the circular terms, $f \tan^2 \theta$ into $(f' \tan^2 \theta - h)$ in the correcting term of ζ, and finally applying to η the term $h \tan v \sin \phi$. It seems better, however, to discard the circular approximation (except as a guide to position) and to put

$$\rho = 2f' \tan \theta \tan^2 \tfrac{1}{2}v \cos \phi - h \tan v \quad \ldots \qquad \ldots (13)$$

This is the polar equation of a limaçon. If the term $-f' \tan^2 \theta \tan v \cos \phi$ in ζ be neglected for the moment (11) may now be written

$$\eta = -\rho \sin \phi$$
$$\zeta = -f' \tan \theta \sec^2 \tfrac{1}{2}v - \rho \cos \phi.$$

It would be tedious and unnecessary to consider possible varieties of form in detail. It is sufficient to take the case in which the limaçon is of the two-looped kind, in which case the relation to the previous double-circular approximation is obvious. The node is at the pole, which is in the same position as in the former case. The positions of two pairs of points are important. These are K, L (fig. 3*c*), given by

$$\phi = \frac{\pi}{2} \text{ and } \frac{3\pi}{2}, \ \eta = \pm h \tan v, \ \zeta = -f' \tan \theta \sec^2 \tfrac{1}{2}v$$

and M, N given by

$$\phi = 0 \text{ and } \pi, \ \eta = 0, \ \zeta = -f' \tan \theta \sec^2 \tfrac{1}{2}v - 2f' \tan \theta \tan^2 \tfrac{1}{2}v \pm h \tan v$$

These points serve to fix the position of the limaçon in relation to the circle obtained by putting $h = 0$.

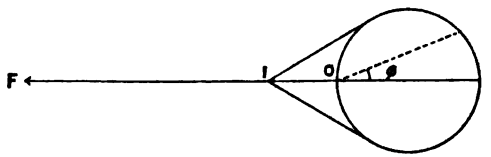


FIG. 3*a*.

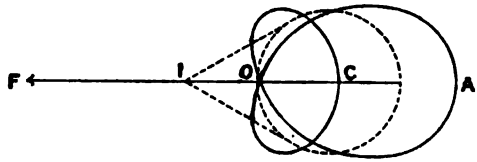


FIG. 3*b*.

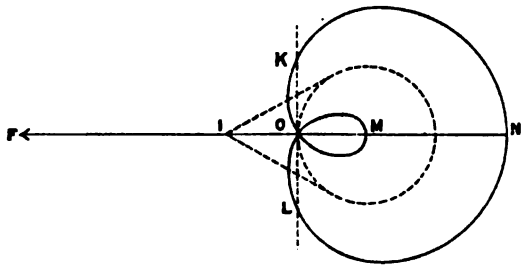


FIG. 3*c*.

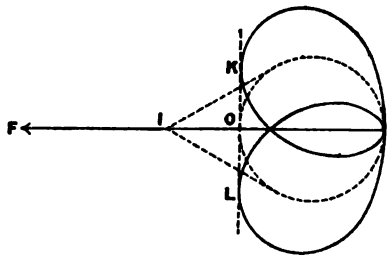


FIG. 3*d*.

18. In order to obtain the final approximation aimed at it is now necessary to replace the additional term in ζ, the general effect of which will be fairly evident. But it seems scarcely worth while to consider the result in detail. For it is clear that the addition will leave the points K, L where $\phi = \frac{\pi}{2}$ and $\frac{3\pi}{2}$ unaltered, and that it will cause the points M and N to move towards each other. The result is therefore very small, and in the most favourable case can only make the points M and N coincide at a point on the circumference of the circular approximation. In fact the point midway between M and N is unchanged in position. It does not seem then that a sufficient improvement in the outer parts of the field can be effected at the expense of the definition at the centre of the field and the lateral aberration of all the images, and it seems almost better to be satisfied with the best possible adjustment at the focus of the mirror. If, however,

special circumstances seem to make it desirable to make a compromise by adjusting the photographic plate so as to get the best definition, or rather the minimum radial aberration at a distance θ from the centre of the plate, then the proper position is given by

$$h = f \tan^2 \theta,$$

in which case the image is generated by a point whose coordinates are

$$\left.\begin{aligned} \eta &= -f' \tan\theta \tan^2 \tfrac{1}{2}v \sin 2\phi + f' \tan^2\theta \tan v \sin\phi \\ \zeta &= -f' \tan\theta \{1 + \tan^2 \tfrac{1}{2}v\,(2 + \cos 2\phi)\} \end{aligned}\right\} \quad \ldots \quad (14)$$

The use of curved plates seems also to offer no advantage sufficient to warrant the extra trouble and expense. The proper radius of curvature for such plates is now found to be

$$R = f^2 \tan^2\theta / 2h = \tfrac{1}{2}f \quad \ldots \quad \ldots \quad (15)$$

a result which is in agreement with the well-known curvature of the field in its usual conventional sense. The impossibility of effectively overcoming the aberration of a parabolic mirror by any device of the kind considered has also been stated by Mr. S. C. Reese (*Astrophysical Journal*, vol. xii. p. 227), after an investigation of a very different kind. As the nature of the images depends on curves given by (14) a typical curve is sketched (fig. 3*d*) with the circle to which it is related in the manner already explained.

19. In conclusion a word or two of summary may be added to what has already been said in § 2 of the critical part of this paper. I still believe that my former paper (*A. J.* No. 435), which gives fig. 3*a* as a fair approximation, may be considered a satisfactory *general* explanation of the nature of the image formed by a parabolic mirror. Moreover its method and results have been of great service in the extension given to the theory in §§ 16–18 above. But confessedly accuracy has in a slight degree been sacrificed for the sake of simplicity. If then my work is to be of use in designing a parabolic mirror for a definite purpose, it will be easy to draw the necessary curves with absolute accuracy with the help of equations (2) of § 4 of the present paper. In most cases the simpler approximate forms (9) and (10) of § 14 will be sufficient. The discussion given in §§ 16–18 is necessarily brief, but it will suffice, I hope, to prove the negative result that more or less kite-shaped images are unavoidable in the case of a reflector as ordinarily adapted for photographic use.

University Observatory, Oxford:
1902 *March* 10.

The Flash Spectrum, Sumatra Eclipse, 1901 *May* 18.

By S. A. Mitchell, Ph.D.

(*Communicated by Professor J. K. Rees.*)

The transparency accompanying this paper contains :

1. Spectrum of the Second Flash.
2. Spectrum taken 5 seconds after Second Flash.

The spectra were photographed with an objective plane grating, and the positives made without enlargement.

The writer, through the courtesy of the former astronomical director of the Naval Observatory, Professor S. J. Brown, became a member of the expedition to view the Sumatra eclipse 1901 May 18.

Before reaching the island, it had been decided to occupy two stations for observations on the eclipse ; one, Solok, near the central line of totality, the other Fort de Koch, near the northern edge of the Moon's shadow path.

On our arrival in the East Indies, it was soon found that the greatest trouble was going to be clouds, for almost at no time during the day was the sky perfectly clear. It was, therefore, thought best to subdivide the party at Solok, and a third station was selected at Sawah Loento, about twenty miles distant, at the terminus of the railroad, where were already Mr. and Mrs. Newall, of Cambridge, England, and a party from the Massachusetts Institute of Technology under the direction of Professor Burton.

Two instruments were taken to Sawah Loento, a camera of 104 inches focus to be used in connection with a cœlostat for photographing the corona ; and a spectroscope consisting of a Rowland flat grating of 15,000 lines, with a ruled surface of $3\frac{1}{2}$ by 5 inches, and a quartz lens of $3\frac{3}{4}$ inch aperture and 72 inches focal length. Light from the Sun, reflected by the cœlostat mirror in a horizontal direction, fell on the grating, where it was diffracted and was brought to a focus on the photographic plate by means of the quartz lens. If grating and photographic plate are each perpendicular to the diffracted beam, the spectrum is "normal." It was arranged to photograph the first order spectrum from λ 3000 to λ 6000.

The final adjustments were made a few days before the eclipse by Mr. L. E. Jewell, the focusing being accomplished by means of a collimator designed by him.

The day of the eclipse dawned clear, and our hopes were that these favourable conditions would remain until after totality, which occurred shortly after noon. First contact was observed

UNITED STATES NAVAL OBSERVATORY

SUMATRA ECLIPSE EXPEDITION

May 18, 1901

5 sec. after Second Flash

Exposure $\frac{1}{2}$ sec.

Second Flash

Exposure 3 sec.

Photographed with an OBJECTIVE PLANE GRATING

BY

S. A. MITCHELL, Columbia University Observatory, New York City

in a perfectly cloudless sky, but soon after this clouds began to gather, and a quarter of an hour before second contact the sky was completely overcast.

The disappearing crescent of the Sun was watched by a binocular, before one half of which was arranged a small plane grating in such a way that with one eye the spectrum could be seen, with the other the Sun itself.

With this, shortly before the time of second contact, bright lines were seen for a few seconds at F and H, and in several places in the green and yellow, but these disappeared almost immediately, the Sun again being completely hidden by clouds—and the first flash passed without our being able to see it.

Towards the middle of totality conditions became a trifle better, so that it was possible to see, through clouds, the corona extending for about half a diameter from the Sun, and with the small spectroscope the "coronium line" quite distinctly. During no time of the $5^m\ 41^s$ of totality was an unclouded view of the corona obtained, but nevertheless the second flash was seen beautifully.

An hour after totality the clouds cleared away and a perfect sky remained for the rest of the afternoon!

Altogether eight exposures were made, one before and one just after totality for the cusp spectrum, one at first and one at second flash, and four with different lengths of exposure during the total phase. The first flash is entirely lacking, clouds having completely cut off all the light; the second flash seemed fully exposed, and it is to the discussion of its photograph that this paper is devoted.

The "Flash."—The peculiarities of this photograph of the flash are twofold:

1. Normal spectrum.
2. Great dispersion.

On the plate, the distance from F to H is 95·4 mm., and, as the spectrum is normal, 1 mm. therefore corresponds to a difference of wave-length of 9·37 tenth-metres, or 1 tenth-metre corresponds to a dispersion of about 0·1 mm. This is about one-fifth the dispersion obtained with the ordinary Rowland mounting with a 21½-foot grating of 20,000 lines.

For some reason the spectra were not in perfect focus, and it was thus practically impossible to measure the cusp spectra. Owing to the great dispersion, although the bright lines of the flash were not perfectly sharp, measures were made and wave-lengths determined with a high degree of accuracy.

The plate was measured by one of the Repsold machines belonging to Columbia University, by comparing the spectrum lines directly with a millimetre scale. Measures with this machine can be made directly to 0·005 mm., and by estimation to 0·0005 mm., *i.e.* to 0·005 λ. However the sharpness of the lines did not permit them to be carried to this degree of accuracy

Comparisons with the Solar Spectrum.—Those who have

attempted to identify the bright lines with Rowland's map know the difficulties of this undertaking, which arise from the differences of dispersion between the solar spectrum and the flash, but more especially from the great differences of intensities of the lines in the two spectra. Great care was exercised in the determinations of the wave-lengths and in the comparisons with Rowland's tables of standard wave-lengths.

The spectrum extends from λ 4924 to λ 3320, but the focus becomes poor at the violet end beyond K, and measures were discontinued at λ 3835, Hη. The photograph from F to H was in the best focus, and for the present purposes considerations are confined to this region.

Neglecting H and He lines, 374 lines were measured in the flash between F and H; 91 of these were unidentified, 283 identified with lines in the solar spectrum. An arbitrary scale of intensities was assumed where 0 denotes a line seen with certainty, 10 the strongest line of the spectrum.

Two points are immediately noticed in comparing the two spectra; first, for each and every element, the brighter the solar line the brighter the flash line corresponding to it; second, the intensities of the solar lines which correspond to a line of given brightness in the flash differ with different metals. Fe and Ni lines of intensity 5, Ti, Sc, and V lines of intensity 2, are identified with flash lines of equal strength. These differences for the various elements were so marked that in order to arrive at their significance, and hence draw some conclusions regarding the 'reversing layer,' three tables were made. The first contains the flash lines arranged according to metals and intensities of lines (scale 0–10); the second the solar lines with which the flash lines were identified arranged according to metals and intensities (scale 1–1000); while the third was made up of all the lines in Rowland's map having an intensity greater than 2 (scale 1–1000).

Although we cannot directly compare the intensities of the bright lines of the flash (scale 0–10) with those of the dark lines given in Rowland's tables (scale 1–1000), we arrive at certain theoretical considerations if we compare the average intensities for the different elements, *i.e.* $\frac{\text{Flash intensities}}{\text{Solar intensities}}$, and also the ratios of the number of lines of each element identified in the flash to the whole number of solar lines for that metal. Forming these ratios, and arranging them, we are at once struck with the systematic variations not only in the ratios of intensities but also in the percentage of lines identified.

The meaning of these systematic differences will be understood if we consider these ratios in combination with the atomic weights of the various elements, as is done in Table I., where also are put down the number of the lines in the flash due to each metal.

TABLE I.

Group I.—Lines strong in flash, and in solar spectrum.

Element.	Atomic Weight.	Number of Lines Identified.	Intensity Flash / Intensity Solar Lines.	Number Lines Identified / Total Number Lines.
Na	23·0	—	—	—
Mg	24·3	1	0·10	1·00
Al	27·1	—	—	—
Ca	40·0	8	0·34	0·38

Group II.—Lines strong in flash, weak in solar spectrum.

Se	44·1	6	0·81	0·75
Ti	48·1	62	0·68	0·70
V	51·2	15	0·68	0·67
Cr	52·1	38	0·55	0·69
Mn	55·1	27	0·24	0·48
Sr	87·6	2	1 08	0·67
Y	88·7	2	0·50	0·67
Zr	90·6	9	0·46	0·70

Group III.—Lines weak in flash, strong in solar spectrum.

Fe	56·0	125	0·23	0 32
Ni	58·7	9	0·36	0·28
Co	59·0	6	0·19	0 29

Looking at the numbers of the two last columns we see that the lines naturally fall into three groups as given in the table.

To these may also be added the following lines :

La, atomic weight 138·5, 3 lines at λ 4123·384, λ 4217·720, and λ 4613·544.

Ba, atomic weight 137, 1 line at λ 4554·211,

and the following lines possibly identified :

Si, atomic weight 12, 1 line at λ 3905·660,

Zn, atomic weight 65, 1 line at λ 4810·724,

Ce, atomic weight 92, 2 lines at λ 4003·912 and λ 4107·649.

In Group I. would also fall Al, if we consider the relative intensities of the two lines λ 3944·160 and λ 3971·674 ; and undoubtedly Na, if our plate took in the D lines.

The grouping of these lines is exactly that adopted by Evershed from his investigations of the Indian eclipse, except I have put Zr with Sr and V in Group II. Mn seems to represent the transition from Group II. to Group III.

As Evershed has pointed out, the remarkable variations of the relative intensities in the flash and Fraunhofer spectra are undoubtedly due to the heights to which the vapours of the different metals ascend in the chromosphere. We would natur-

ally expect that these heights vary according to the atomic weights of the metals, those of least atomic weights ascending to the greatest distances; and generally speaking this no doubt is true. But if we have two gases in the Sun's atmosphere, one a gas with an intrinsic brightness 1 and 100 miles in thickness, it would give a photographic line in the flash spectrum just as bright as the other gas of intrinsic brightness 100 and only 1 mile thick, *if* the Sun and Moon were relatively at rest during the period of the flash; but considering the gradual advance of the Moon in covering up successive layers of the Sun's atmosphere we see that in the emission spectrum the photographic brightness of the fainter gas would be many times that of the brighter. The absorption caused by a gas depends on the total number of molecules the solar ray comes in contact with, and will be very nearly equal in the two cases.

In view of these considerations it would therefore seem that the gases of the metals of Group II. extend very high, that they are nowhere very much condensed, and that practically all the gas contributes to the formation of the emission line, and hence, the flash lines are to be regarded as true reversals of the corresponding solar lines.

The vapours of Groups I. and III. are somewhat condensed near the Sun's surface (those of Group I., particularly Ca, reach far greater heights than those of Group III.), but as it is the upper portion that contributes most to the formation of the emission lines owing to the progressive motion of the Moon, the flash lines are to be regarded as only partial reversals of the Fraunhofer lines, the solar intensities being greater than the flash intensities.

Unknown Lines.—Taking account of lines in the flash identified with groups in the solar spectrum, about half the solar lines have corresponding lines in the flash. From the above considerations we see that it is highly improbable that lines of intensity 2 in the solar spectrum, and belonging to Groups I. and III., will have lines corresponding to them of sufficient brightness to show in this photograph of the flash. In fact, although there are 135 Fe lines of intensity 2 in Rowland's map between F and H, only 11 of these are found in the flash; and indeed great numbers of the feebler solar lines have no counterpart in the flash spectrum. But if, on the other hand, we compare the stronger lines, we see that every strong line of the solar spectrum almost without exception is found in the flash.

And so, remembering the meaning of the differences of intensity, we see no reason for giving up our faith in the existence of the "reversing layer."

Columbia University, New York City:
1902 *January* 28.

The Duration of Totality at Navalmoral.

By C. T. Whitmell, M.A., B.Sc.

For the total solar eclipse of 1900 May 28 I have shown, by a comparison of a large number of observations of the predicted and observed durations of totality for several localities, that the eclipse semidiameter of the Moon, adopted by the *British Nautical Almanac*, is too large. (See *Total Solar Eclipse of* 1900, pp. 75–81.) In the present paper I propose to give some details with regard to Navalmoral, whence I observed this eclipse.

For Navalmoral the following data were published by Dr. Downing :—

Adopted position, 5° 34′ W. longitude, 39° 52′ N. latitude.

		G.M.T. h m s
Eclipse begins	May 28	2 48 45
Totality „	„	4 6 12
Totality ends	„	4 7 39
Eclipse „	„	5 15 45

	Angle from N. Point. °
First contact	273
Second „	99
Third „	267
Fourth „	93

A note was appended to the effect that the predicted duration of totality (87ˢ) is perhaps 3ˢ too long.

The duration of totality at Navalmoral was carefully timed independently by four observers, and we agreed upon a totality of 80ˢ. Mr. Howarth, F.R.A.S., the Rev. S. J. Johnson, F.R.A.S., and Mr. Southall used only the eye unaided.

I observed with a low-power binocular, of which the right object-glass was fitted with a diffraction grating attached to a prism, so that the beginning and the ending of totality were estimated by the disappearance and the reappearance of the normal solar spectrum. The coincidence in the four estimates seems to afford reasonable ground for believing that the duration of totality was, as nearly as possible, 80ˢ.

There is thus a loss of at least 7ˢ to be accounted for, and this may be due to :—(*a*) errors in the lunar tables, (*b*) error in the adopted position of Navalmoral, (*c*) error in the *N.A.* value of the Moon's geocentric semidiameter, which for eclipses is 15′ 32″·65 at mean distance. It is assumed that the *N.A.* eclipse semidiameter of the Sun is correct.

With regard to (*a*) it should be noted that, as the transit of the Moon over the Sun was practically central, it may be inferred that any allowable error in the Moon's tabular latitude would be insufficient appreciably to alter the duration of totality.

As to (*b*) Señor Iñiguez, of the Madrid Observatory, has courteously supplied the exact position of Navalmoral Church. The coordinates are 5° 32′ 29″ W. longitude, and 39° 53′ 29″ N. latitude, the difference from the originally adopted coordinates being only 1′ 31″ in longitude and 1′ 29″ in latitude.

By *N.A.* data, at mid-totality, $4^h\ 6^m\ 56^s$, G.M.T., the centre of the shadow was in 5° 31′ 45″ W. longitude, and 39° 53′ 40″ N. latitude, coordinates differing by only 44″ of longitude and 11″ of latitude from the position of the church as given by Señor Iñiguez. As we were about half a mile N. of the church we were only some 20″ of latitude N. of the central line, so small a distance that for us the transit of the Moon over the Sun was practically central during totality.

We have now to consider (*c*). Adopting for Navalmoral the data supplied by Señor Iñiguez, and using *N.A.* data for the R.A., Dec., and semidiameters of the Sun and Moon, I have made for $4^h\ 0^m$, $4^h\ 7^m$, and $4^h\ 10^m$, G.M.T., a careful computation of the positions of the Sun and Moon, and obtain a totality duration of 88^s, or just one second in excess of the *N.A.* predicted value. The moment of mid-totality agrees almost exactly with the *N.A.* time, $4^h\ 6^m\ 56^s$. The nearest approach of the centres of the Sun and Moon is about 0″·3, so that, as already pointed out, the transit was practically central. The position angle for second contact is about 93°, that for third contact is about 271°, reckoned eastward from the Sun's north point.

Thus we have really to account for a loss of about 8^s. It will be found that to reduce the duration of totality to 80^s the effective apparent eclipse semidiameter of the Moon, as seen by the observer during totality, must be reduced from its *N.A.* value of 16′ 5″·71 to 16′ 3″·97, a reduction of 1″·74; whilst the geocentric mean semidiameter at the time of totality must be reduced from 15′ 55″·40 to 15′ 53″·68, a reduction of 1″·72, so that, finally, the *N.A.* geocentric mean distance eclipse semidiameter of 15′ 32″·65 must be reduced to 15′ 30″·97, a reduction of 1″·68, corresponding to 3″·36 for the diameter. The Sun's apparent semidiameter at totality comes out as 15′ 46″·59 by *N.A.* data, and is considered to be accurate.

In a paper by Mr. Dyson, giving an account of the total eclipse of 1901 May 18 (*Proc. R.S.* vol. lxix.), it is stated that the observed duration of totality at Aoer Gadang, Sumatra, was 10^s less than that predicted by the *N.A.*, but agreed closely with a prediction based on a value of 15′ 31″·47 for the geocentric mean semidiameter of the Moon. This value, Dr. Downing informs me, was arrived at by Herr Peters (of the Berlin *Jahrbuch*) after a discussion of the eclipse of 1900 May 28.

If we adopt this value for the Navalmoral eclipse, totality

should have lasted $82^s{\cdot}4$. The loss of $2^s{\cdot}4$, needed to produce agreement with our observations, could be accounted for by a reduction of only $0''{\cdot}5$ in the Moon's semidiameter, *i.e.* of $1''$ in her diameter. This discrepancy may reasonably be attributed to irregularities in the Moon's limb, as suggested by Mr. Crommelin in *Monthly Notices*, vol. lxi. pp. 52–3. A lunar valley of a depth of about 6,000 feet below the Moon's mean level, or two valleys, the sum of whose depths amounts to 6,000 feet, one valley being near second and the other near third contact, would be sufficient.

As the points of second and third contact were about position angles 93° and 271°, and the Moon's north pole at the time of the eclipse was 11° 13′ W. of her north point, the position angles of contact on the Moon's limb would be about 104° and 282° from her north pole. The Moon's libration in latitude was practically zero, that in longitude was +4°. The position angles may easily be 1° or 2° in error, for an extremely slight deviation from central transit produces a considerable change in these angles. The angles 99° and 267°, given by the *Nautical Almanac*, would apparently correspond to a difference of some $2''$ between the centres of the Sun and Moon about mid-totality.

Adopting the angles 104° and 282°, second contact of the Moon with the Sun would occur near 86° E. longitude and 14° S. latitude, whilst third contact would be near 94° W. longitude and 12° N. latitude. The second contact indicates a region between the Cordilleras and the D'Alembert Mountains. The third contact is not on the lunar maps, being on that face of the Moon not shown by them, but the region indicated is in the neighbourhood (N.W.) of Neper, a walled plain.

Mr. Saunder, to whom I wrote about these localities, remarks that it is not possible, from our present knowledge, to say whether the neighbourhood of the Moon's limb near the contact points is above or below the mean level. But he adds that this information might be obtained from photographs taken during the eclipse, or taken at times when the Moon was under libration, similar to that which she had during the eclipse.

It is well known that the lunar border in the vicinity of second contact was seen to be very irregular during the progress of this eclipse. It will be of interest for some one possessed of suitable lunar photographs to investigate the regions of the Moon's limb referred to above.

Dr. Struve (*Monthly Notices*, vol. lii. p. 283) states that there is no systematic deviation of the form of the Moon's disc from a circle, and Professor Franz (*Monthly Notices*, vol. lxi. p. 264) concludes that the Moon's figure is sensibly spherical. Thus surface irregularities seem to be the only thing left to account for the discrepancy, still outstanding at Navalmoral, when Herr Peters's value of the semidiameter is used.

The estimated value of the Moon's telescopic mean semidiameter has undergone some interesting changes. According to the late Mr. Stone (*Monthly Notices*, vol. xlii. p. 42) the

adopted value for 1750–1815 was 15′ 34″·27; for 1816–39 it was 15′ 33″·95; for 1840–61 it was 15′ 34″·68; and in and after 1862 it was 15′ 34″·08. The present (1900) value used in the *Nautical Almanac* is 15′ 34″·09, the mean horizontal parallax being 57′ 2″·28.

In the Preface to the *Nautical Almanac* for 1897 there appeared, for the first time, special values of the semidiameters of the Sun and Moon for use in eclipses and occultations, the value for the Sun being 15′ 59″·63 (Auwers), and for the Moon 15′ 32″·65 (Struve). For 1900 the American Ephemeris adopts 15′ 31″·76 for the eclipse semidiameter of the Moon.

There seems to be but little doubt that we need to use *three* different values for the Moon's semidiameter; the largest value for ordinary telescopic purposes, the intermediate for the occultations of stars, and the smallest for solar eclipses.

I would draw the attention of those interested in this subject to a very able article by Professor Oudemans, published in the *Monthly Notices*, vol. xxvi. pp. 249–260, 1866 May. He therein discusses the duration of occultations and eclipses, refers to the effect of indentations on the Moon's limb, and draws the conclusion that for occultations the Moon's mean semidiameter is 15′ 32″·27, but that for eclipses it is only 15′ 31″·02. The difference 1″·25 between these values agrees very nearly with the difference 1″·18 between the *Nautical Almanac* value, 15′ 32″·65, and that recently deduced by Herr Peters, 15′ 31″·47.

I am much indebted to Mr. Crommelin for independent confirmation of the principal computations in this paper.

Leeds: 1901 *December.*

Mean Areas and Heliographic Latitudes of Sun Spots in the Year 1901, deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lxi. p. 533, and are deduced from the measurements of photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1901; and Table II. gives the same particulars for the entire year 1901 and the twelve preceding years for the sake of comparison. The areas are given in two forms: first, projected areas, that is to

say, as seen and measured on the photographs, these being expressed as millionths of the Sun's apparent disc; and next areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1901 the mean daily area of the whole spots, and the mean heliographic latitude of the spotted area, for spots north and for spots south of the equator; together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results from 1889 to 1900 being added, as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill* by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon of 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas.					
			Projected.			Corrected for Foreshortening.		
			Umbræ.	Whole Spots.	Faculæ.	Umbræ.	Whole Spots.	Faculæ.
	1900. d							
632	Dec. 24·64	26	0·0	0·5	0·0	0·0	0·3	0·0
	1901.							
633	Jan. 20·98	27	2·4	8·0	13	1·9	6·6	16
634	Feb. 17·32	26	6·9	22	29	5·0	16	36
635	Mar. 16·65	26	0 0	0·0	7·0	0·0	0·0	9·8
636	Apr. 12·93	27	0·0	0·0	0·0	0·0	0·0	0·0
637	May 10·18	28	138	339	53	83	231	72
638	June 6·39	27	14	70	34	8·8	46	42
639	July 3·59	27	0·0	0·9	47	0·0	1·1	54
640	July 30 80	25	0·0	0·0	6·2	0·0	0·0	6·6
641	Aug. 27·03	28	0·0	0·4	2·2	0·0	0·3	3·2
642	Sept. 23·29	27	2·5	10	8·1	1·4	5·4	7·1
643	Oct. 20·58	27	5·2	29	94	5·5	31	130
644	Nov. 16·88	27	9·7	51	4·0	6·4	35	7·7

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270
1893	362	327	1983	2287	234	1464	2404
1894	364	317	1728	1666	231	1282	1877
1895	364	237	1330	2059	169	974	2278
1896	364	127	745	1243	90	543	1410
1897	364	122	695	977	88	514	1149
1898	363	93	532	767	64	375	891
1899	364	27	159	297	18	111	337
1900	360	22	101	150	17	75	180
1901	359	14	41	23	8·6	29	29

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	1900. d			°		°	°	°
632	Dec. 24·64	26	0·0	...	0·3	10·20	−10·20	10·20
	1901.							
633	Jan. 20·98	27	0·0	...	6·6	8·20	− 8·20	8·20
634	Feb. 17·32	26	15	3·71	1·2	4·95	+ 3·04	3·81
635	Mar. 16·65	26	0·0	...	0·0	...	...	...
636	Apr. 12·93	27	0·0	...	0·0	...	...	...
637	May 10·18	28	2·31	8·66	0·0	...	+ 8·66	8·66
638	June 6·39	27	3·8	9·69	8·6	19·48	− 4·30	11·55
639	July 3·59	27	0·1	2·10	1·0	1·68	− 1·17	1·73
640	July 30·80	25	0·0	...	0·0	...	...	...
641	Aug. 27·03	28	0·3	36·37	0·0	...	+36·37	36·37
642	Sept. 23·29	27	0·0	...	5·4	8·85	− 8·85	8·85
643	Oct. 20·58	27	0·0	...	3·1	14·91	−14·91	14·91
634	Nov. 16·88	27	0·0	...	35·0	20·21	−20·21	20·21

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
1889	360	5·0	7·26	73·0	11·90	−10·68	11·61
1890	361	53·1	22 20	46·3	21·75	+ 1·73	21·99
1891	363	401	20·49	169	19·91	+ 8·52	20·31
1892	362	607	15·09	607	21·69	− 3 29	18·39
1893	360	517	14·91	941	14·26	− 3 93	14·49
1894	364	543	12·31	739	15·56	− 3·75	14·18
1895	364	565	14·26	409	12·54	+ 3·01	13·54
1896	364	203	13·60	340	14·77	− 4·15	14·33
1897	364	196	8 32	318	7·73	− 1·62	7·96
1898	363	110	9·82	266	10·77	− 4·75	10·49
1899	364	23	6·18	88	10·43	− 6·95	9·54
1900	360	26	6·61	49	8·34	− 3·12	7·74
1901	359	22	8·59	6·6	16·27	+ 2·82	10·37

The principal features of the record for 1901 are :—

1. The decline in area of umbræ, whole spots, and faculæ has still continued, and has been most marked ; the relative decrease in mean daily spotted area for 1901 as compared with 1900 being greater than for 1900 as compared with 1899.

2. The decrease in the area of the umbræ has been proportionally less than that for the whole spots.

3. The decrease in the area of the faculæ on the other hand has been very remarkable. The area registered—twenty-nine millionths—is by far the lowest for any year of the Greenwich solar record, the next lowest being ninety millionths for 1878.

4. Except for a single outburst the northern hemisphere has been practically quiescent for the entire year. But that outburst was so much the greatest that it contributed, in its two appearances, 74 per cent. of the entire spotted area of the year, and in consequence of it the mean daily area for the northern hemisphere was more than three times as great as for the southern.

5. Comparing 1901 with 1900 the decrease for the northern hemisphere was only 15 per cent., whilst for the southern it was 86 per cent. The decrease, therefore, has been almost entirely in the southern hemisphere.

6. The only notable outburst of the year was the group referred to above. This was seen first on the east limb on May 19, the morning after the total solar eclipse of May 18. At the times of the eclipse as seen in Mauritius and Sumatra

respectively the centre of the group was 93° and 92° distant from the central meridian, and therefore only just out of sight behind the east limb. The group was situated in N. lat. 9°, and a fine prominence is seen in the Mauritius photographs of the eclipse, rising from the limb in N. lat. 6°, *i.e.* just over the southern end of the spot group. A comparison of the Mauritius and Sumatra eclipse photographs shows that a considerable change has taken place in the form of this prominence in the interval of about 100 minutes which separated the two series of observations. To the north of the prominence, and therefore directly over the spot group itself, the corona is seen on both series of photographs as much disturbed.

The spot group appeared a second time on the east limb on June 16, but had diminished in size, almost to disappearance, before it reached the west limb on June 26.

7. The distribution of the spots in latitude in 1901 shows some tendency in the mean to seek a higher latitude than in 1900, four groups, two in each hemisphere, appearing in latitudes above 20°. But the relatively great area of the group of May 19, in N. lat. 9°, brings the mean distance from the equator of all spots down to 10°·37. This shows a distinct rise in latitude over 1900, when the mean distance was 7°·74. In the closing years of the preceding cycle the mean distance for 1888 was 7°·39, and for 1889, the year of minimum, 11°·61, whilst for 1890, the first year of increased spotted area, it was 21°·99.

8. The number of days without spots has very greatly increased, there having been no fewer than 289 such days out of the 359 days for which there are photographs available. On 277 days neither spots nor faculæ were shown on the photographs. The days for which the photographic record is deficient are January 13, January 24, February 27, April 3, August 3, and August 5.

9. The mean daily spotted area—twenty-nine millionths—for 1901 is much smaller than that for 1889, the year of the last minimum, which was seventy-eight; but it has not fallen quite so low as at the preceding minimum of 1878, when it was only twenty-four. The very slight activity in 1901, and the very large proportion of days on which no spots were seen, together with the appearance of four groups in latitude 20° or above, point to 1901 being probably the year of minimum. These four high latitude groups may, indeed, indicate the commencement of the revival, a view which receives some confirmation from the appearance on March 3 of the present year of two groups, one of them of considerable size, in N. lat. 25°.

1902 *March* 11.

Results of Micrometer Measures of Double Stars made with the 28-inch Refractor at the Royal Observatory, Greenwich, in the year 1901.

(*Communicated by the Astronomer Royal.*)

The measures were made with a bifilar position-micrometer on the 28-inch refractor, aperture 28 inches, focal length 28 feet. The power generally used was 670, but when the definition permitted a power of 1120 was employed for observing very close pairs. A blue glass shade was employed to diminish the light and irradiation when bright stars were observed. The observations were made in variously coloured fields or in a dark field with illuminated wires. The initials in the last column are those of the observers, viz. :—

B. Mr. Bryant. L. Mr. Lewis. W.B. Mr. Bowyer.

Micrometric Observations of Double Stars at the Royal Observatory, Greenwich.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
Σ 3062 ...	0 1	32 7	345·0	1·46	1	6·9 8·0	·753	B.
β 253	0 5	32 2	42·5	0·52	2	8·3 8·4	·436	B.
β 485	0 6	31 48	304·9	0·41	1	8·7 8·8	·753	B.
Krueger 1 ...	0 6	32 43	186·4	1·92	1	9·2 9·5	·753	B.
β 1026 ...	0 7	36 56	329·2	0·29	1	8·1 8·9	·753	B.
β 864	0 8	55 13	283·9	1·14	1	8·4 11·5	·036	L.
OΣ 2	0 8	63 34	37·4	0·68	1	6·5 8·0	·044	L.
			39·0	0·54	2	...	·853	W.B.
			36·0	0·60	2	...	·896	B.
Σ 19	0 12	53 55	133·9	2·06	2	7·0 9·5	·022	L.
			135·5	2·22	1	...	·890	W.B.
β 1093 ...	0 15	79 34	70·7	0·28	1	7·3 8·2	·830	B.
β 1015 ...	0 16	78 14	113·9	0·49	1	8·4 8·6	·835	W.B.
OΣ 7 B.C.	0 16	24 5	107·4	0·54	1	9·0 10·0	·753	B.
β 1156 ...	0 21	26 7	34·5	0·45	1	9·2 9·3	·753	B.
OΣ 12	0 26	36 2	147·1	0·42	1	5·6 5·9	·082	L.
			149·5	0 55	2	...	·436	B.
OΣ 15	0 30	41 32	311·4	0·16	2	7·5 8·5	·436	B.
β 257	0 35	43 17	229·9	0·46	1	8·1 8·8	·753	B.
OΣ 18	0 37	86 23	128·4	1·07	1	7·4 9·5	·835	W.B.
β 865	0 38	47 18	198·5	1·40	1	8·3 8·8	·753	B.
β 866	0 40	47 18	69·1	1·70	1	9·0 9·1	·753	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
β 495	0 42	71 51	223·6	0·49	3	7·5 7·7	·850	W.B.
Σ 60	0 43	32 43	220·4	...	1	4·0 7·6	·082	L.
(η Cassiopeiæ)			223·5	5·40	1	...	·753	B.
OΣ 20	0 49	71 22	319·6	0·45	2	6·0 6·4	·896	W.B.
Σ 73	0 49	66 55	21·5	0·91	4	6·2 6·8	·622	W.B.
β 1099 ...	0 51	30 11	324·3	0·11	2	6·2 6·2	·436	B.
β 302	0 53	69 9	106·0	0·56	3	6·8 8·0	·300	W.B.
β 1228 ...	1 0	77 13	276·8	0·64	2	8·3 8·9	·896	W.B.
β 303	1 4	66 44	286·3	0·60	1	7·2 7·2	·025	W.B.
β 235	1 5	39 30	93·9	0·64	1	7·0 7·5	·118	B.
Σ 113	1 15	91 2	352·4	1·56	1	6·2 7·2	·830	B.
β 4	1 18	79 9	66 9	0·33	1	7·8 8·8	·830	B.
β 1164 ...	1 22	85 10	157·7	0·26	1	6·7 7·0	·830	B.
β 506	1 26	75 10	16·4	1·25	1	4·0 10·5	·865	L.
(η Piscium)								
Σ 158	1 41	57 20	261·4	1·95	2	8·3 8·8	·032	W.B.
β 509	1 38	80 56	253·2	0·65	1	8·4 8·7	·830	B.
β 1016 ...	1 42	57 25	22·7	0·47	1	8·7 8·7	·923	W.B.
Ho. 311 ...	1 46	45 38	176·1	0·36	3	7·5 7·5	·923	W.B.
Σ 183 A.B.	1 49	61 41	354·6	0·38	4	7·5 8·2	·499	W.B.
A.C.		...	163·5	5·42	2	7·5 8·9	·940	W.B.
Σ 186	1 51	88 39	204·3	0·39	2	7·2 7·2	·819	B.
OΣ 38	1 58	48 10	112·0	0·32	1	5·0 6·2	·053	L.
(γ^2 Andromedæ)			117·1	0·27	1	...	·118	B.
Σ 208	1 58	64 33	71 8	0·61	3	6 2 8·4	·653	W.B.
Σ 228	2 8	42 59	88·6	0·40	1	6·7 7·6	·118	B.
Σ 231	2 8	92 52	231·4	16·24	1	6·0 7·8	·098	L.
			232·0	15·95	1	...	·112	W.B.
β 519	2 25	92 42	37·0	0·55	1	8·3 8·9	·098	L.
OΣ 44	2 36	47 44	232·3	1·23	1	7·8 8·5	·923	W.B.
β 262	2 42	59 22	63·9	1·62	3	8·2 9·6	·369	W.B.
Σ 305	2 42	71 2	314·7	3·01	2	7·3 8·0	·497	W.B.
β 524	2 47	52 5	203·6	0·22	1	5·5 6·5	·008	L.
			17·88	0·13	1	...	·118	B.
Σ 333	2 53	69 4	201·6	1·02	2	5·7 6·0	·021	W.B.
			200·2	1·55	1	...	·865	L.
β 525	2 53	68 47	144·1	0·31	3	7·5 7·5	·621	L.
β 1173 ...	2 53	66 16	330·8	0·34	1	7·7 8·8	·986	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1901.	Obs.
Σ 346	2 59	65 8	94·1	0·49	2	6·0 6·0	·040	W.B.
			94·0	0·43	1	...	·808	B.
*	2 59	65 9	166·6	1·93	1	...	·913	L.
β 83	2 41	95 23	103·3	0·92	1	7·9 9·4	·830	B.
β 1030 ...	3 4	68 39	155·2	0·49	1	8·5 8·5	·077	W.B.
			164·6	0·56	2	...	·524	B.
			159·3	0·49	1	...	·986	L.
β 530	3 8	67 25	188·6	1·77	1	9·7 10·1	·986	L.
β 84	3 11	96 17	27·4	0·75	1	6·8 7·3	·830	B.
OΣ 53 ...	3 11	51 44	232·0	0·54	1	7·2 8·0	·923	W.B.
β 878	3 23	67 32	75·0	1·37	1	5·8 13·0	·986	L.
Σ 412	3 29	65 52	19·9	0·30	1	6·6 6·9	·077	W.B.
			6·6	0·24	3	...	·622	B.
β 533	3 29	58 39	44·3	0·48	2	8·0 8·0	·058	W.B.
			53·3	0·49	1	...	·808	B.
Σ 425	3 33	56 10	268·3	2·37	2	7·3 7·3	·021	W.B.
β 536	3 40	66 6	293·2	0·19	1	8·2 8·7	·939	B.
			319·2	0·30	1	...	·986	L.
β 538	3 42	66 12	135·2	2·06	1	10·0 10·5	·986	L.
β 1184... ...	3 42	67 56	272·6	0·39	1	8·0 8·5	·923	W.B.
			271·3	0·58	1	...	·939	B.
OΣ 516 ...	3 44	58 1	42·4	2·09	1	7·2 9·2	·923	W.B.
OΣ 531 ...	4 1	52 12	129·8	1·99	1	8·5 10·2	·112	W.B.
Ho. 326 ...	4 3	61 37	180·8	0·32	1	8·5 8·5	·939	B.
OΣ 77	4 10	58 33	178·0	0·22	1	7·5 7·5	·118	B.
OΣ 80	4 16	47 49	183·2	0·45	1	6·5 7·0	·112	W.B.
			180·1	0·51	2	...	·452	B.
OΣ 74	4 7	80 36	288·4	0·36	1	8·0 8·5	·939	B.
Σ 535	4 18	78 51	320·2	1·70	2	6·7 8·2	·517	W.B.
Aldebaran ...	4 30	73 42	110·0	30·54	1	1 13·5	·036	L.
OΣ 86	4 31	70 27	44·6	0·53	1	7·5 7·5	·099	L.
			61·3	0·43	3	...	·667	W.B.
			55·3	0·43	1	...	·118	B.
*	4 30	70 15	190·4	0·39	1	7·5 8·0	·099	L.
			192·1	0·41	1	...	·121	W.B.
Σ 567	4 31	70 43	319·1	1·70	1	8·5 9·0	·099	L.
			318·5	1·82	2	...	·099	W.B.
Σ 572	4 32	63 18	22·0	3·81	1	6·5 6·5	·077	W.B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1901.	Obs.
	h m	° ′	°	″					
β 883 ...A.B.	4 46	79 6	68·8	0·38	3	7·5	7·8	·612	L.
			64·2	0·26	3	...		·384	B.
			59·7	0·31	2	...		·117	W.B.
A.C.	...		156·0	18·10	1	7·5	13·0	·099	L.
β 1047...A.B.	5 3	62 5	48·6	0·26	1	7·2	8·8	·246	L.
Σ 645 ...A.C.	...		27·3	11·62	1	7·2	9·2	·246	L.
β 885	5 6	91 54	25·1	0·56	1	8·3	8·4	·118	B.
β 555 ...B.C. (Rigel)	5 10	98 19	179·3	0·36	1	8	8	·036	L.
Σ 668 ...A.B.	...		201·7	9·70	1	1	8	·036	L.
Dawes 5 ...	5 19	92 29	79·8	1·08	1	3·5	5·5	·085	B.
β 889 ...A.B.	5 21	55 40	220·7	1·02	1	8·5	8·8	·246	L.
A.C.	...		98·3	3·62	1		14·0	·246	L.
A.D.	...		108·6	12·58	1		13·8	·246	L.
Σ 707 ...A.E.	...		131·6	18·40	1		9·4	·246	L.
A.F.	...		189·3	27·78	1		10·1	·246	L.
Σ 749	5 31	63 8	168·8	0·74	2	7·1	7·2	·137	W.B.
β 1240...A.B.	5 32	59 34	336·4	0·22	2	5·6	6·0	·124	B.
			331·1	0·18	2	...		·281	L.
A.C.	...		267·4	12·24	1	5·6	8·7	·268	L.
OΣ 112 ...	5 33	52 6	73·6	0·61	1	7·5	7·5	·151	B.
			66·0	0·62	3	...		·287	L.
β 1032 ...	5 34	92 39	328·4	0·31	1	4·0	5·0	·173	B.
OΣ 119 ...	5 43	82 4	323·2	0·72	1	7·5	8·3	·085	B.
β 560	5 43	60 18	166·7	0·69	2	8 0	8·5	·091	B.
Σ 799	5 43	51 28	180·7	0·80	2	7·2	8·3	·308	L.
Aitken 54 A.B.	6 3	60 45	347·0	0·58	2	7·6	8·5	·270	L.
A.C.	...		312·1	51·86	1	...		·296	L.
β 1058... ...	6 4	66 59	264·0	0·31	2	7·2	7·5	·091	B.
			273·1	0·27	1	...		·293	L.
Σ 899	6 17	72 22	20·5	2 26	2	7·0	8·0	·140	W.B.
β 1021 ...	6 25	61 32	82·5	0·76	2	8 1	9·4	·285	L.
OΣ 149 ...	6 30	62 38	280·0	0·72	2	6·5	9·0	·280	L.
Σ 945	6 33	48 56	267·4	0·72	2	7·1	8·0	·265	L.
			263·5	0·83	1	...		·309	W.B.
OΣ 156 ...	6 42	71 42	301·9	0·67	3	6·5	7·0	·111	B.
			310·4	0·58	1	...		·233	W.B.
Σ 1037 ...	7 7	62 35	301·0	0·89	2	7·0	7·1	·155	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
Σ 1066 ...	7 14	67 50	211·0	7″·44	1	3·2 8·2	·233	W.B.
β 579	7 27	56 40	28·7	0·96	1	8·0 10·5	·323	L.
Σ 1110 ...	7 28	57 54	226·0	5·62	1	2·7 3·7	·044	L.
(Castor)			223·6	5·75	2	...	·154	W.B.
OΣ 175 ...	7 28	58 49	338·4	0·75	2	6·0 6·6	·174	B.
			332·6	0·63	2	...	·230	W.B.
			329·9	0·61	1	...	·323	L.
OΣ 177 ...	7 35	52 20	127·6	0·61	1	7·5 8·5	·233	W.B.
			122·7	0·58	2	...	·388	B.
			125·9	0·56	2	...	·308	L.
β 580	7 39	61 44	137·1	1·45	1	2·0 14·3	·312	L.
(Pollux C.D)								
β 101	7 47	103 38	302·7	0·48	1	5·2 6·5	·315	B.
OΣ 185 ...	7 52	88 36	24·1	0·26	1	6·8 7·0	·304	B.
β 581 A.B.	7 59	77 26	291·3	0·28	3	8·5 8·6	·195	B.
			282·0	0·68	1	...	·312	L.
A.C.		...	200·0	5·57	1	11·0	·312	L.
Σ 1184 ...	8 3	51 49	340·8	27·37	1	8·0 8·5	·227	W.B.
			341·0	26·97	1	...	·293	L.
Σ 1186 ...	8 3	62 13	220·6	3·51	1	7·1 10·4	·293	L.
Σ 1187 ...	8 3	57 28	43·1	2·37	3	7·1 8·0	·256	W.B.
Σ 1196 A.B.	8 6	72 3	5·6	0·84	1	5·0 5·7	·176	L.
ζ Cancri			2·2	1·08	2	...	·270	W.B.
A.C.		...	113·0	5·44	1	5·0 6·5	·176	L.
			114·3	5·51	2	...	·270	W.B.
B.C.		...	124·1	6·12	1	5·7 6·5	·176	L.
			126·3	6·20	2	...	·270	W.B.
Σ 1202 ...	8 8	78 51	318·2	2·43	1	7·7 9·8	·296	W.B.
β 1244 ...	8 9	87 43	43·8	0·70	2	7·9 8·1	·239	B.
Σ 1211 ...	8 12	50 42	133·3	1·17	1	8·7 9·2	·233	W.B.
Σ 1216 ...	8 16	91 17	202·0	0·47	1	7·5 8·2	·304	B.
β 585	8 36	69 10	111·4	0·41	1	7·5 9·0	·255	W.B.
			116·7	0·37	2	...	·315	B.
β 209	8 37	50 50	357·8	1·72	1	8·2 8·7	·233	W.B.
Σ 1273 ...	8 41	83 13	232·3	3·51	2	3·5 7·7	·269	L.
ε Hydræ A.C.								
Schiaparelli A.B.		...	280·6	0·11	2	3·5 6·0	·284	L.
			272·3	0·18	3	...	·306	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
β 1068 ...	8 44	80 46	172·7	0·45	1	7·7 8·8	·306	L.
			178·9	0·36	1	...	·315	B.
*	8 45	81 21	43·9	3·06	1	...	·277	W.B.
Perrotin ...	8 46	81 17	338·5	0·71	2	7·5 8·7	·306	B.
			349·7	0·53	1	...	·306	L.
β 587	8 47	96 48	137·6	0·73	1	6·0 9·0	·315	B.
Σ 1321 ...	9 8	36 52	65·3	19·05	1	7·1 7·2	·298	B.
Σ 3121 ...	9 12	61 00	17·9	0·77	1	7·5 7·8	·085	B.
			21·6	0·66	2	...	·272	W.B.
			20·6	0·84	1	...	·294	L.
OΣ 201 ...	9 18	61 39	221·8	1·39	3	7·5 8·9	·287	W.B.
			218·1	1·43	1	...	·293	L.
β 105	9 19	63 2	200·6	2·58	1	5 10·5	·293	L.
*	9 19	63 33	17·6	3·40	1	9·5 10·0	·293	L.
Σ 1348... ...	9 19	83 14	319·9	1·86	2	7·5 7·6	·287	W.B.
			319·9	1·98	1	...	·290	L.
Aitken ...	9 20	58 25	46·0	0·90	1	8·7 10·2	·323	L.
Σ 1356 ...	9 23	80 27	111·6	0·64	3	6·2 7·0	·291	B.
			112·1	...	1	...	·361	L.
Σ 1374... ...	9 35	50 35	284·5	...	1	7·0 8·3	·364	W.B.
Σ 1385... ...	9 44	72 55	182·4	1·19	1	8·5 10·7	·312	L.
OΣ 208 ...	9 45	35 28	290·8	0·32	4	5·0 5·6	·297	B.
Σ 1389... ...	9 47	62 33	306·3	2·32	3	8·0 9·0	·294	W.B.
			313·0	2·15	1	...	·312	L.
A.C. 5... ...	9 48	97 36	89·7	0·35	2	5·5 5·7	·307	B.
OΣ 215 ...	10 11	71 45	211·5	0·93	2	6·7 7·0	·222	B.
			206·3	0·88	3	...	·316	W.B.
			212·4	1·01	2	...	·317	L.
Σ 1424 ... γ Leonis	10 14	69 38	114·1	3·77	4	2·0 3·5	·299	W.B.
			116·9	...	1	...	·359	L.
Σ 1426 A.B.	10 15	83 4	283·4	0·76	1	7·8 8·3	·296	W.B.
			280·1	0·77	2	...	·321	B.
			291·7	...	1	...	·361	L.
A.C.		...	6·2	7·54	1	7·8 9·3	·296	W.B.
			12·2	...	1	...	·361	L.
OΣ 216 ...	10 17	74 9	123·2	1·40	1	7·0 10·5	·312	L.
Σ 1429 ...	10 19	64 53	249·7	0·99	4	8·1 8·5	·305	W.B.
			248·2	0·65	1	...	·323	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
OΣ 217 ...	10 21	72 16	148·8	0·87	2	7·3 7·8	·222	B.
			145·1	0·88	3	...	·310	W.B.
OΣ 218 ...	10 22	85 56	75·5	0·82	2	7·3 9·2	·321	B.
Σ 1457 ...	10 33	83 45	316·6	1·35	1	7·4 8·4	·296	W.B.
			314·1	...	1	...	·361	L.
OΣ 224 ...	10 34	80 38	296·5	0·39	2	7·2 9·2	·321	B.
OΣ 225 A.B.	10 35	70 14	243·3	0·92	2	7·5 11·2	·307	L.
A.C.			351·8	6·30	2	7·5 9·8	·307	L.
OΣ 227 ...	10 36	78 44	348·5	0·61	2	7·5 8·5	·293	B.
			345·2	0·65	2	...	·306	L.
OΣ 228 ...	10 42	66 54	188·3	0·58	2	7·2 8·1	·222	B.
			185·2	0·41	1	...	·288	W.B.
			191·9	0·57	2	...	·318	L.
OΣ 229 ...	10 42	48 21	318·4	0·85	4	6·7 7·1	·256	B.
β 915	10 44	65 11	230·1	1·57	1	9·0 9·2	·312	L.
			227·2	1·42	1	...	·315	B.
Ho. 378 ...	10 59	51 2	225·3	0·48	3	8 8·1	·289	B.
Ho. 48... ...	10 59	66 18	12·1	1·46	1	8·3 11	·236	L.
Σ 1517 ...	11 8	69 19	267·4	0·52	3	7·3 7·3	·233	B.
			265·8	0·44	1	...	·312	L.
			272·5	...	1	...	·364	W.B.
Σ 1523 ... (ζ Ursæ Maj.)	11 13	57 54	147·5	2·29	1	4·0 4·9	·323	L.
			146·8	2·28	4	...	·342	W.B.
Σ 1527 ...	11 14	75 11	16·6	3·01	2	6·9 3·1	·370	W.B.
			17·4	3·40	2	...	·374	L.
Σ 1536 ...	11 19	78 55	55·7	2·43	2	3·9 7·1	·370	W.B.
			49·7	2·39	2	...	·372	L.
Lalande 21846	11 24	58 59	9·5	0·69	1	7 11	·288	W.B.
			8·8	0·92	3	...	·290	L.
OΣ 234 ...	11 25	48 10	144·1	0·26	3	7·0 7·4	·352	B.
			137·9	0·27	1	...	·504	L.
OΣ 235 ...	11 26	28 22	121·5	0·42	1	6·0 7·3	·501	B.
			124·7	0·47	1	...	·504	L.
Σ 1554 ...	11 31	76 36	250·4	0·78	1	8·9 9·1	·315	B.
			251·9	0·96	1	...	·383	L.
Σ 1555 A.B.	11 31	61 40	350·3	0·32	2	6·4 6·8	·272	L.
			352·1	0·39	4	...	·301	B.
Σ 1555 A.C.	11 31	61 40	146·7	20·79	1	6·4 10·3	·288	W.B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
OΣ 237 ...	11 34	48 18	263·4	1·20	1	7·4 9·0	·504	L.
Σ 1586 ...	11 52	49 6	249·0	1·48	1	8·2 10·2	·504	L.
Σ 1606 ...	12 6	49 33	331·3	0·97	1	6·3 7·0	·392	B.
			330·3	0·97	2	...	·510	L.
Σ 1639 ...	12 19	63 52	357·7	0·30	3	6·5 8·0	·289	L.
			1·4	0·30	2	...	·321	B.
Σ 1643 ...	12 22	62 25	39·8	2·12	2	8·3 8·6	·292	W.B.
			41·0	1·98	3	...	·360	L.
Σ 1647 ...	12 25	79 44	220·5	1·57	3	7·5 8·0	·345	W.B.
			220·4	1·26	3	...	·378	L.
Σ 1661 ...	12 30	78 3	237·0	2·65	1	8·5 8·5	·288	W.B.
			237·1	2·51	2	...	·386	L.
Σ 1658 ...	12 30	82 0	357·2	2·28	2	8 0 9·8	·386	L.
Σ 1663 ...	12 32	68 15	100·0	0·56	2	7·8 8·7	·292	W.B.
			103·2	0·66	1	...	·315	B.
			105·5	0·67	2	...	·386	L.
Σ 1670 ... (γ Virginis)	12 37	90 54	144·5	5·86	1	3·0 3·0	·375	W.B.
Ho. 256 ...	12 39	53 41	130·6	0·49	1	6·5 9·0	·236	L.
Σ 1687 A.B.	12 48	68 13	82·7	1·27	4	5·1 7·8	·364	W.B.
			83·1	1·19	2	...	·402	L.
Σ 1687 A.C.	12 48	68 13	126·3	28·60	1	5·1 9·0	·421	L.
OΣ 256 ...	12 51	90 25	74·2	0·55	3	7·2 7·6	·313	B.
β 1081... ...	12 55	58 41	343·0	5·26	1	4·5 14·0	·421	L.
β 1082... ...	12 56	33 6	100·9	1·15	1	6·0 9·6	·515	L.
Σ 1711 ...	12 58	75 59	345·9	0·91	2	8·5 9·0	·402	L.
β 929	12 59	93 7	222·8	0·46	2	6·2 6·2	·313	B.
OΣ 260 ...	13 3	62 31	125·3	0·65	2	7·9 8·3	·364	L.
			123·6	...	1	...	·326	B.
			122·3	0·69	1	...	·419	W.B.
Σ 1728 ...	13 5	71 57	196·7	0·31	3	6·0 6·0	·370	L.
			196·6	0·28	1	...	·326	B.
			195·4	0·16	1	...	·419	W.B.
β 930	13 1	44 12	120·2	2·74	1	6·0 11·3	·515	L.
β 1083 A.B.	13 1	60 27	223·0	6·74	1	6·5 11·5	·422	L.
B.C.		...	221·3	0·35	1	11·5 11·7	·422	L.
*	13 2	62 31	202·9	0·42	1	9·0 9·5	·422	L.

Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
		h m	° ′	°	″				
O∑ 261	...	13 7	57 23	347·0	1·33	1	7·0 7·5	·390	L.
				343·0	1·52	3	...	·434	W.B.
β 800 ...	...	13 12	72 27	117·6	2·66	2	7·1 10·2	·348	L.
∑ 1734	...	13 16	86 32	188·5	...	1	7·2 7·9	·367	L.
∑ 1742	...	13 19	88 5	347·8	...	1	7·4 7·9	·367	L.
Ho. 260	...	13 19	60 15	323·6	0·78	2	8·3 8·5	·364	L.
				314·7	...	1	...	·326	B.
				316·2	0·78	1	...	·419	W.B.
O∑ 266	...	13 24	73 47	337·9	1·65	1	7·3 7·8	·375	W.B.
				391·8	1·92	2	...	·385	L.
O∑ 269	...	13 28	54 34	211·0	0·32	1	6·5 7·0	·392	B.
				218·0	0·38	1	...	·422	L.
				219·4	0·27	2	...	·430	W.B.
∑ 1768	...	13 33	53 13	130·3	1·12	3	5·0 7·6	·448	W.B.
				130·6	0·89	1	...	·534	B.
β 612 ...	...	13 35	78 45	230·4	0·30	1	6·3 6·5	·392	B.
				228·7	0·25	2	...	·463	W.B.
∑ 1785	...	13 45	62 31	285·0	1·26	2	7·2 7·5	·430	W.B.
				280·1	1·40	1	...	·389	L.
β 1270	...	13 59	81 2	15·1	0·31	1	8·2 8·3	·507	W.B.
∑ 1808	...	14 6	62 56	255·3	2·73	1	8·0 9·0	·389	L.
				254·8	2·52	1	...	·485	W.B.
O∑ 278	...	14 8	45 21	88·6	0·31	2	7·5 7·5	·403	B.
				90·2	0·39	1	...	·504	L.
				90·3	0·24	1	...	·507	W.B.
∑ 1819	...	14 10	86 24	177·5	1·33	1	7·9 8·0	·485	W.B.
∑ 1820	...	14 10	34 13	254·5	2·00	1	8·2 8·5	·515	L.
β 1272	A.B.	14 14	40 47	136·1	1·31	3	8·4 9·5	·446	L.
				129·2	1·47	1	...	·507	W.B.
	A.C.			320·5	24·22	1	8·4 8·5	·504	L.
β 1273...	...	14 15	41 37	184·5	1·08	2	8·6 10·8	·332	L.
∑ 1834	...	14 17	41 2	202·0	0·23	1	7·1 7·2	·359	L.
				179·0	0·1	1	...	·504	L.
				219·4	0·18	3	...	·311	B.
∑ 1863	...	14 35	38 0	92·9	0·52	1	7·1 7·4	·507	W.B.
				89·4	0·69	1	...	·515	L.
∑ 1865	...	14 36	75 51	150·9	0·31	2	3·5 3·9	·348	L.
				151·8	0·36	4	3·5 3·9	·394	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
O Σ 237 ...	11 34	48 18	263·4	1·20	1	7·4 9·0	·504	L.
Σ 1586 ...	11 52	49 6	249·0	1·48	1	8·2 10·2	·504	L.
Σ 1606 ...	12 6	49 33	331·3	0·97	1	6·3 7·0	·392	B.
			330·3	0·97	2	...	·510	L.
Σ 1639 ...	12 19	63 52	357·7	0·30	3	6·5 8·0	·289	L.
			1·4	0·30	2	...	·321	B.
Σ 1643 ...	12 22	62 25	39·8	2·12	2	8·3 8·6	·292	W.B.
			41·0	1·98	3	...	·360	L.
Σ 1647 ...	12 25	79 44	220·5	1·57	3	7·5 8·0	·345	W.B.
			220·4	1·26	3	...	·378	L.
Σ 1661 ...	12 30	78 3	237·0	2·65	1	8·5 8·5	·288	W.B.
			237·1	2·51	2	...	·386	L.
Σ 1658 ...	12 30	82 0	357·2	2·28	2	8 0 9·8	·386	L.
Σ 1663 ...	12 32	68 15	100·0	0·56	2	7·8 8·7	·292	W.B.
			103·2	0·66	1	...	·315	B.
			105·5	0·67	2	...	·386	L.
Σ 1670 ... (γ Virginis)	12 37	90 54	144·5	5·86	1	3·0 3·0	·375	W.B.
Ho. 256 ...	12 39	53 41	130·6	0·49	1	6·5 9·0	·236	L.
Σ 1687 A.B.	12 48	68 13	82·7	1·27	4	5·1 7·8	·364	W.B.
			83·1	1·19	2	...	·402	L.
Σ 1687 A.C.	12 48	68 13	126·3	28·60	1	5·1 9·0	·421	L.
O Σ 256 ...	12 51	90 25	74·2	0·55	3	7·2 7·6	·313	B.
β 1081... ...	12 55	58 41	343·0	5·26	1	4·5 14·0	·421	L.
β 1082... ...	12 56	33 6	100·9	1·15	1	6·0 9·6	·515	L.
Σ 1711 ...	12 58	75 59	345·9	0·91	2	8·5 9·0	·402	L.
β 929	12 59	93 7	222·8	0·46	2	6·2 6·2	·313	B.
O Σ 260 ...	13 3	62 31	125·3	0·65	2	7·9 8·3	·364	L.
			123·6	...	1	...	·326	B.
			122·3	0·69	1	...	·419	W.B.
Σ 1728 ...	13 5	71 57	196·7	0·31	3	6·0 6·0	·370	L.
			196·6	0·28	1	...	·326	B.
			195·4	0·16	1	...	·419	W.B.
β 930	13 1	44 12	120·2	2·74	1	6·0 11·3	·515	L.
β 1083 A.B.	13 1	60 27	223·0	6·74	1	6·5 11·5	·422	L.
B.C.		...	221·3	0·35	1	11·5 11·7	·422	L.
*	13 2	62 31	202·9	0·42	1	9·0 9·5	·422	L.

Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
		h m	° ′	°	″				
OΣ 261	...	13 7	57 23	347·0	1·33	1	7·0 7·5	·390	L.
				343·0	1·52	3	...	·434	W.B.
β 800 ...	...	13 12	72 27	117·6	2·66	2	7·1 10·2	·348	L.
Σ 1734	...	13 16	86 32	188·5	...	1	7·2 7·9	·367	L.
Σ 1742	...	13 19	88 5	347·8	...	1	7·4 7·9	·367	L.
Ho. 260	...	13 19	60 15	323·6	0·78	2	8·3 8·5	·364	L.
				314·7	...	1	...	·326	B.
				316·2	0·78	1	...	·419	W.B.
OΣ 266	...	13 24	73 47	337·9	1·65	1	7·3 7·8	·375	W.B.
				391·8	1·92	2	...	·385	L.
OΣ 269	...	13 28	54 34	211·0	0·32	1	6·5 7·0	·392	B.
				218·0	0·38	1	...	·422	L.
				219·4	0·27	2	...	·430	W.B.
Σ 1768	...	13 33	53 13	130·3	1·12	3	5·0 7·6	·448	W.B.
				130·6	0·89	1	...	·534	B.
β 612 ...	...	13 35	78 45	230·4	0·30	1	6·3 6·5	·392	B.
				228·7	0·25	2	...	·463	W.B.
Σ 1785	...	13 45	62 31	285·0	1·26	2	7·2 7·5	·430	W.B.
				280·1	1·40	1	...	·389	L.
β 1270	...	13 59	81 2	15·1	0·31	1	8·2 8·3	·507	W.B.
Σ 1808	...	14 6	62 56	255·3	2·73	1	8·0 9·0	·389	L.
				254·8	2·52	1	...	·485	W.B.
OΣ 278	...	14 8	45 21	88·6	0·31	2	7·5 7·5	·403	B.
				90·2	0·39	1	...	·504	L.
				90·3	0·24	1	...	·507	W.B.
Σ 1819	...	14 10	86 24	177·5	1·33	1	7·9 8·0	·485	W.B.
Σ 1820	...	14 10	34 13	254·5	2·00	1	8·2 8·5	·515	L.
β 1272	A.B.	14 14	40 47	136·1	1·31	3	8·4 9·5	·446	L.
				129·2	1·47	1	...	·507	W.B.
	A.C.			320·5	24·22	1	8·4 8·5	·504	L.
β 1273...	...	14 15	41 37	184·5	1·08	2	8·6 10·8	·332	L.
Σ 1834	...	14 17	41 2	202·0	0·23	1	7·1 7·2	·359	L.
				179·0	0·1	1	...	·504	L.
				219·4	0·18	3	...	·311	B.
Σ 1863	...	14 35	38 0	92·9	0·52	1	7·1 7·4	·507	W.B.
				89·4	0·69	1	...	·515	L.
Σ 1865	...	14 36	75 51	150·9	0·31	2	3·5 3·9	·348	L.
				151·8	0·36	4	3·5 3·9	·394	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
Σ 2107 ...	16 48	61 10	332·6	0·36	2	6·7 8·5	·676	L.
Σ 3107 ...	16 54	85 53	93·4	1·45	1	8·5 8·5	·545	B.
Σ 2118 ...	16 56	24 49	95·5	0·15	3	5·5 6·5	·625	B.
Σ 2114 ...	16 57	81 24	159·5	1·35	1	6·2 7·4	·496	W.B.
			160·2	1·16	1	...	·545	B.
β 357	17 1	79 19	299·3	1·02	1	8 4 9·4	·712	L.
Σ 2130 ...	17 3	35 24	145·5	2·27	1	5·0 5·1	·797	B.
β 1118 ...	17 5	105 36	251·0	0·33	3	3·4 3·9	·571	B.
Σ 2140 ... (α Herculis)	17 10	75 30	112·1	4·87	1	3·0 6·1	·718	W.B.
Σ 2145 ...	17 12	63 17	56·6	0·52	1	8·3 8·9	·411	L.
			45·7	0·63	1	...	·657	L.
OΣ 327 ...	17 12	33 46	313·0	0·20	1	7·6 8·0	·797	B.
β 628	17 15	57 14	346·7	0·57	1	9·0 9·5	·427	L.
β 629	17 15	57 14	344·1	1·15	1	8·4 8·7	·427	L.
β 630	17 17	57 40	227·3	1·58	1	8·5 9·6	·427	L.
Σ 2163 ...	17 20	47 47	90·7	1·64	2	9·2 9 2	·433	L.
β 1249 ...	17 21	36 3	81·6	0·47	1	8·8 8·9	·433	L.
β 1250 ...	17 21	59 9	70·2	1·75	2	9·4 9·5	·433	L.
Σ 2173 ...	17 25	90 59	327·7	0·94	4	6 0 6·3	·627	B.
β 631	17 35	90 36	63·1	0·34	4	7·5 7·6	·630	B.
Σ 2199	17 37	34 12	90·0	1·59	2	7·2 7 8	·433	L.
β 1251	17 38	74 0	65·2	1·24	2	6·0 11·5	·507	L.
Σ 2203 ...	17 38	48 18	317·0	0·67	2	7·5 7·8	·433	L.
			319·7	0·70	1	...	·643	W.B.
Σ 2205 ...	17 40	72 14	305 7	2·24	1	8·3 8·7	·518	W.B.
			307·4	2·15	3	...	·552	L.
Σ 2214 A.B.	17 40	46 13	213·1	19·16	1	8·3 8·8	·430	L.
De. B.C.	17 40	46 13	142·6	1·16	1	8·8 10·3	·430	L.
Σ 2215 ...	17 41	72 15	292·4	0·75	2	5·9 7·9	·529	W.B.
			295·1	0·61	3	...	·552	L.
Ho. 70 ...	17 42	59 25	104·0	0·53	3	8 8	·425	L.
A.C. 7... ...	17 43	62 13	61·7	1·52	2	10·0 10·5	·507	L.
OΣ 337 ...	17 46	82 44	280·4	0·36	3	7·5 8·0	·611	B.
OΣ 338 ...	17 47	74 39	18·1	0·58	2	6·5 7·0	·529	W.B.
			15·1	0·67	1	...	·545	B.
A.C. 8... ...	17 49	60 18	75·6	0·30	1	8·0 9·8	·731	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
A.C. 9... ...	17 50	60 10	55·8	1·01	3	8·4 8·7	·552	W.B.
			55·8	1·10	1	...	·731	B.
Σ 2262 ...	17 57	98 11	258·6	1·93	1	5·0 5·7	·687	B.
Σ 2272 ... 70 Ophiuchi	18 0	87 28	227·5	1·58	10	4·3 6·3	·598	W.B.
Σ 2275 ...	18 0	50 39	133·1	0·66	3	9·0 9·2	·466	L.
OΣ 341 ...	18 1	68 34	88·3	0·49	1	6·4 7·7	·559	L.
			86·2	0·30	3	...	·654	B.
A.C. 15 ...	18 3	59 27	319·6	1·07	1	5·4 9·0	·482	L.
Σ 2281 ...	18 4	86 1	236·2	0·22	1	6·7 7·2	·633	B.
Σ 2283 ...	18 5	83 52	83·5	0·93	2	7·2 7·7	·540	W.B.
Σ 2289 ...	18 6	73 32	228·8	1·22	4	6·5 7·0	·563	W.B.
Σ 2294 ...	18 9	89 51	86·5	0·18	2	7·4 7·7	·660	B.
β 1091 ...	18 9	51 26	26·4	0·25	1	8·6 8·6	·731	B.
β 641	18 18	68 32	339·8	0·84	2	7·5 9·0	·569	W.B.
β 1203 ...	18 18	89 15	71·2	0·24	2	7·5 7·7	·682	B.
Σ 2315 ...	18 21	62 40	193·1	0·34	4	7·5 9·0	·561	L.
			202·4	0·24	1	...	·539	W.B.
Ho. 84 ...	18 20	62 40	319·5	4·08	3	9·0 10·0	·518	L.
Σ 2318 ...	18 21	64 4	254·1	20·75	1	7·9 10·0	·482	L.
*	18 22	64 2	138·8	1·50	1	9·5 10·0	·482	L.
*	18 23	64 2	263·7	2·94	1	9·5 10·0	·542	L.
OΣ 351 ...	18 23	41 18	23·7	0·59	2	8·0 8·3	·754	B.
OΣ 543 ...	18 23	43 10	133·4	1·08	2	7·2 9·2	·754	B.
OΣ 357 ...	18 31	78 21	239·3	0·39	1	7·5 7·6	·539	W.B.
			247·3	0·43	1	...	·633	B.
OΣ 358 ...	18 31	73 6	193·0	1·87	3	6·8 7·2	·543	W.B.
Σ 2356 ...	18 34	61 23	60·4	0·89	2	8·2 8·6	·619	L.
			56·0	1·15	2	...	·619	W.B.
*	18 34	61 18	253·4	1·11	1	9·0 10·0	·600	W.B.
			251·0	1·14	1	...	·695	L.
Ho. 87 ...	18 34	73 34	103·0	0·45	1	7·8 8·1	·539	W.B.
Ho. 437 A.B.	18 37	58 27	120·9	0·30	2	8·3 8·5	·511	L.
C.D.	...		341·2	3·48	2	11·2 11·7	·511	L.
Σ 2367 ...	18 37	59 48	94·1	0·24	4	7·2 7·6	·568	L.
			76·0	0·23	1	...	·631	B.
Σ 2369 ...	18 39	87 29	96·8	0·97	1	7·5 8·0	·687	B.
Σ 2375 ...	18 41	84 36	113·7	2·37	2	6·2 6·6	·605	W.B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
Σ 2400 A.B.	18 44	73 51	182·9	1·88	1	8·0 10·6	·745	L.
A.C.		...	187·8	3·08	1	8·0 11·0	·745	L.
Σ 2402 ...	18 45	79 26	207·2	0·84	1	8·0 8·4	·638	W.B.
β 265	18 45	78 36	226·3	1·30	1	7·7 9·3	·742	L.
Hussey 199...	18 47	78 19	4·3	0·19	1	8·7 9·1	·745	L.
β 648	18 53	57 14	220·0	1·11	2	6·0 9·5	·608	L.
Σ 2422 ...	18 53	64 2	95·9	0·91	3	7·6 7·7	·614	W.B.
Σ 2424 ...	18 54	76 31	264·6	16·68	1	5·7 9·2	·745	L.
β 649	18 55	57 40	5·1	1·54	1	8·5 10·7	·673	L.
Σ 2437 ...	18 57	70 58	65·4	0·77	3	7·8 8·2	·627	W.B.
β 287	19 1	76 17	63·4	5·76	1	3 13·0	·742	L.
Σ 2454 ...	19 2	59 43	247·0	0·69	1	8·0 9·2	·643	W.B.
Σ 2455 ...	19 3	67 59	80·0	3·43	2	7·2 8·3	·619	W.B.
Ho. 98 ...	19 4	63 4	145·8	0·24	1	8 8	·841	B.
β 1204 ...	19 7	87 33	195·4	0·35	2	7·7 8·5	·709	B.
Σ 2488 ...	19 11	70 9	325·7	1·50	1	8·5 9·7	·638	W.B.
OΣ 368 ...	19 12	74 1	216·1	0·96	2	7·3 8·5	·619	W.B.
OΣ 371 ...	19 12	62 43	158·7	0·83	2	7 7	·628	B.
			150·8	0·84	2	...	·641	W.B.
β 1256 ...	19 14	83 51	39·2	0·71	3	8·2 8·3	·698	B.
β 141	19 18	67 41	90·3	0·81	1	7·5 8·5	·575	L.
			84·6	0·82	1	...	·643	W.B.
*	19 19	67 41	281·3	0·78	1	9·0 10·0	·643	L.
β 1129 ...	19 19	37 49	329·7	0·28	1	6·3 6·3	·797	B.
Σ 2525 ...	19 22	62 52	319·8	0·51	3	7·4 7·6	·650	L.
			313·0	0·55	1	...	·643	W.B.
σ 623	19 27	62 15	54·6	34·69	2	3 7	·704	L.
Σ 2556 ...	19 35	67 58	142·6	0·37	1	7·3 9·8	·731	B.
β 658	19 40	63 7	295·5	0·39	1	6·5 9·5	·731	B.
A. G. C. 11...	19 45	71 6	151·9	0·18	5	5·7 8·8	·712	B.
Ho. 580 ...	19 49	67 48	273·8	0·66	2	8 8·1	·704	B.
β 1258 ...	19 56	60 22	153·5	1·40	2	8·0 10·7	·627	L.
*	19 57	60 20	130·0	3·40	2	9·2 9·8	·627	L.
β 439 ...	19 57	60 25	237·6	3·25	2	7·9 12·7	·627	L.
Σ 2616 ...	19 58	75 42	265·0	3·23	1	6·8 9·7	·769	W.B.
OΣ 395 . .	19 58	65 21	100·4	0·55	1	5·5 6·0	·580	L.
			102·0	0·57	2	...	·578	B.
			103·6	0·64	2	...	·641	W.B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1901.	Obs.
	h m	° ′	°	″				
Σ 2620 ...	19 59	78 30	291·1	1·78	2	8·2 9·3	·742	W.B.
Σ 2624 ...	20 0	54 15	173·2	1·76	1	7·2 7·8	·715	W.B.
β 57	20 1	74 47	118·0	2·37	1	6·7 11·3	·745	L.
Σ 2695 ...	20 28	64 32	80·6	1·11	1	6·2 8·0	·580	L.
			81·8	1·19	2	...	·641	W.B.
β 670	20 28	76 24	39·3	0·51	2	8·5 8·9	·717	L.
*	20 28	76 23	140·7	0·43	2	9·0 9·5	·717	L.
β 151 ... A.B. (β Delphini)	20 33	75 45	14·0	0·54	3	4·5 6·0	·634	L.
			16·8	0·45	8	...	·681	B.
			14·6	0·39	2	...	·641	W.B.
A.C.	...		119·1	25·11	1	...	·832	L.
A.D.	...		330·3	37·80	1	...	·832	L.
Σ 2729 ...	20 46	96 0	234·0	0·26	2	5·9 7·2	·694	B.
β 367	20 51	62 28	133·3	0·40	1	8·0 6·0	·772	L.
Σ 2737 ...	20 54	86 5	285·3	0·62	4	5·7 8·6	·707	B.
OΣ 424 ...	20 55	74 49	313·1	0·42	1	7·5 8·7	·580	L.
			321·2	0·43	2	...	·742	B.
β 69	20 58	68 46	315·2	0·82	1	8·3 9·1	·580	L.
Σ 2744 ...	20 58	88 52	163·0	1·37	3	6·3 7·0	·717	B.
Σ 2749...A.B.	21 0	86 51	155·2	4·13	1	7·7 8·9	·772	L.
A.D.	....	...	153·2	...	1	7·7 8·9	·772	L.
Secchi ...B.C.	...	...	334·8	0·88	1	8·9 10·0	·772	L.
OΣ 527 ...	21 3	85 15	267·4	0·29	2	6·5 8·6	·709	B.
γ Equulei ...	21 5	80 16	273·3	2·33	1	5·0 11·5	·559	L.
Ho. 152 ...	21 8	62 4	326·5	0·43	3	8·5 9·5	·869	W.B.
OΣ 535 ... (δ Equulei)	21 10	80 24	196·2	0·22	1	4·1 4·1	·534	B.
			196·3	0·21	1	...	·622	B.
			179·0	0·24	1	...	·654	B.
			71·7	0·08	1	...	·687	B.
			69·3	0·11	1	...	·701	B.
			64·1	0·11	1	...	·731	B.
			66·3	0·05	1	...	·753	B.
			64·5	0·09	1	...	·764	B.
			54·4	0·06	1	...	·797	B.
			55·1	0·11	1	...	·830	B.
			50·8	0·12	1	...	·841	B.
OΣ 535 ...	21 10	80 24	185·0	0·21	1	...	·543	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1901.	Obs.
δ Equulei ...	...	...	193·1	0·27	1	...		·559	L.
			193·9	0·22	1	...		·577	L.
			161·2	...	1	...		·696	L.
			210·3	<0·1	1	...		·746	L.
			210·6	<0·1	1	...		·776	L.
			185·0	<0 1	1	...		·860	L.
			196·5	<0·1	1	...		·865	L.
			203·0	<0·1	1	...		·959	L.
β 838	21 16	87 18	100·2	1·42	2	7·8	9·5	·742	B.
Σ 2799 ...	21 24	79 21	298·0	1·47	2	7·0	7·0	·842	W.B.
Σ 2804 ...	21 28	69 44	332·2	2·75	2	7·3	8·0	·853	W.B.
β 1212 ...	21 34	90 30	274·1	0·47	3	6·5	6·9	·738	B.
Σ 2822 ...	21 40	61 42	122·1	2·60	1	4·0	5·0	·868	L.
Ho. 166 ...	21 40	62 38	96·0	0·32	2	7·5	7·5	·690	L.
			90·6	0·34	1	...		·534	B.
β 989 A.B. (κ Pegasi)	21 40	64 49	243·2	0·11	1	3·9	5·0	·008	L.
			236·2	0·14	1	...		·036	L.
			210·3	0·11	1	...		·515	L.
			185·4	0·10	1	...		·542	L.
			194·2	0·12	1	...		·559	L.
			191·7	0·10	1	...		·636	L.
			167·4	0·06	1	...		·865	L.
			236·6	0·14	3	...		·030	W.B.
			182·2	0·09	1	...		·871	W.B.
			204·7	0·12	4	...		·680	B.
			194·7	0·10	2	...		·836	B.
Σ 2825 ...	21 42	89 36	116·2	0·91	4	8·0	8·2	·769	B.
Ho. 171 ...	21 48	62 41	173·6	0·84	2	8	8	·737	B.
			177·5	1·03	2	...		·850	L.
Ho. 179 ...	22 8	60 20	268·5	0·43	1	8·0	8·5	·835	W.B.
Σ 2878 ...	22 10	82 31	124·2	1·11	2	6·5	9·0	·814	B.
Σ 2881 ...	22 10	60 55	100·3	1·30	2	7·7	8·2	·786	B.
Ho. 180 ...	22 12	46 38	225·6	0·51	1	7·0	7·5	·953	B.
Σ 2900 ...	22 19	69 39	178·1	1·34	1	6·0	9·2	·835	W.B.
β 172	22 19	95 21	7·1	0·56	4	5·6	6·0	·745	B.
β 291	22 23	88 59	162·7	0·33	1	8·4	8·7	·830	B.
Σ 2912 ...	22 24	86 5	91·4	0·23	2	5·8	7·2	·814	B.
Σ 2934 ...	22 37	69 5	136·1	0·98	2	8·2	9·2	·786	W.B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1901.	Obs.
	h m	° ′	°	″					
Σ 2944 ...	22 43	94 44	260·1	3·41	2	7·0	7·5	·781	B.
OΣ 483 ...	22 54	78 48	222·3	0·94	2	6·2	7·7	·842	W.B.
β 79	23 12	92 4	87·1	1·03	3	8·0	8·6	·786	B.
β 80	23 14	85 8	19·6	0 23	3	8·0	8·8	·786	B.
β 1222 ...	23 23	86 59	38 0	1·20	2	9	9	·814	B.
β 1266 ...	23 25	59 44	14·3	0·22	4	8·9	9·0	·664	L.
β 720	23 28	59 14	342·3	0·32	3	5·9	6·0	·563	L.
			335·5	0·30	3	...		·859	B.
β 858	23 36	58 0	261·6	0·54	4	8·0	8·2	·669	L.
A. G. C. 14...	23 39	61 2	200·4	1·40	2	5·0	9·5	·941	L.
Barnard ...	23 42	85 19	170·0	0·60	1	8·6	8·6	·797	B.
Σ 3050 ...	23 54	56 50	214·4	2·55	2	6·0	6·0	·886	W.B.
β 733	23 57	63 26	239·6	0·66	3	6·0	11·0	·592	L.
Σ 3056 ...	23 59	56 17	142·6	0·57	1	7	8	·044	L.
			145·3	0·53	2	...		·792	B.
β 862	23 59	52 23	314·3	0·58	1	8·5	9·0	·044	L.

Capella.

Observer ... ... Mr. Lewis.

Date 1901. G.M.T.	Hour Angle.	Day from Beginning of the Year.	Position Angle.	Remarks.
d h			° ′	
Jan. 4 7¼	3½E.	3·3	36 8	Powers 670 and 1120. Observed without blue shade. Undoubtedly elongated, and quite as distinct as κ Pegasi—better definition here. Star surrounded by some fifteen rings. Measures of distance were made to verify the elongation. The diameter of the star was measured first in the direction of apparent elongation, and then at right angles to this direction, the measures being made by placing the inside edges of the wires tangential to the disc. (1) Sum of direct readings, o″·138. Sum of reverse readings, o″·115. ½ (difference), o″·0115. (2) Sum of direct readings, o·135. Sum of reverse readings, o·125. ½ (difference), o″·0050. If the discs are assumed equal, then the separation of centres is o″·0065 = o″·076.

Date 1901. G.M.T.	Hour Angle.	Day from Beginning of the Year.	Position Angle.	Remarks.
d h	h		° ′	
Jan 14	7½ 4 E.	13·3	17 1	Powers 670 and 1120. Images very fine. A large number of rings, easier than κ Pegasi; but the definition was better when measuring Capella than it was when measuring κ Pegasi. Measures made in the same way as on January 4. (1) Sum of direct readings, 0r·174. Sum of reverse readings, 0r·093. ½ (difference), 0r·041. (2) Sum of direct readings, 0r·164. Sum of reverse readings, 0r·094. ½ (difference), 0r·035. If the discs are assumed equal, then the separation of centres is 0r·096 = 0″·072. κ Pegasi measured in the same way gave 0″·108. Both Capella and κ Pegasi were measured in the usual way by trying to make the centres of the wires tangential to the discs; the results were: 0″·132 for Capella. 0″·137 for κ Pegasi.
Mar. 26	8½ 3½W.	84·3	285 7 or 105 7	Power 670. Elongation not so apparent as on January 14.
Apr. 1	7¾ 3½W.	90·3		Power 670. Definition very fine. A large number of rings; as nearly round as I have seen it. There may be an elongation in 213°·7 or 33°·7, which would probably be due to the shaking of the instrument. Windy.
9	8¾ 5 W.	98·3		Powers 670 and 1120. Definition fair. If any elongation it is in 272° 3 or 92°·3.
17	7½ 4 W.	106·3		Powers 670 and 1120. Splendid definition. Star apparently round.
18	7¾ 4½W.	107·3		Powers 670 and 1120. Definition very good. A large number of rings. Actual disc very minute. A slight elongation suspected in 310°, which might be due to the trembling of the instrument.
23	7½ 4¼W.	112·3		Power 670. Definition very good. Image steady. Set at 20°, but could not detect any elongation.
29	7¼ 5 W.	118·3		Powers 670, 840, and 1120. Definition very good and image steady. With 670 and 840 the star appeared round; with 1120 a very slight elongation was suspected at 327°·5 or 147°·5.

Date 1901. G.M.T.		Hour Angle.	Day from Beginning of the Year.	Position Angle.	Remarks.
d	h			° ′	
Nov. 14	10½	3½E.	317·4		Powers 670 and 1120. Star nucleus very small indeed and beautifully defined. A large number of rings almost perfect and circular. If the disc is not round the elongation is at 263°·2 or 83°·2.
Observer ... ... Mr. Bryant.					
Mar. 1	3	3¾E.	59·1	207 25	Power 670. Clouds passing. Very windy. Occasional glimpses of fine definition through thin clouds. Two blue shades used.
Apr. 17	6	2½W.	106·3	30 48	Power 670. Definition fine through thin cloud. Elongation very slight.
20	0	3 E.	109·0	28 25	Power 670. Very windy. Sky very clear. Star very bright. Seeing at intervals excellent when wind dropped. Two blue shades used. With power 1120 effect of wind greater, preventing measures.
22	5½	2½W.	111·2	14 12	Power 670. Definition fair. Star small and steady. Thin clouds. Elongation very slight. Two blue shades used.
26	5½	2½W.	115·2	359 5	Power 670. Very windy. Definition fair momentarily. Clouds passing.
30	5¼	3 W.	119·2	344 55	Powers 670 and 1120. Definition very fine indeed, but elongation very slight. Measures give distance about 0″·08 (power 1120). Distance thought to be really less than measures indicate. Two blue shades used.
May 24	5½	4½W.	143·2	267 29	Power 670. Very windy, otherwise definition at times good. Blue shades used. Too windy to use higher power. Measures of distance give 0″·09.
July 4	0½	2½W.	184·0	135 25	Power 670. Hazy. Image very unsteady, but small. Two blue shades used.
11	0	2½W.	191·0	112 51	Power 670. Definition fair at long intervals. Sky hazy. Two blue shades used. Apparently this is the right quadrant.
Aug. 18	22	2¾W.	229·9	326 40	Power 670. Sky hazy. Definition fair. N.E. wind. Quadrant seems to be right. Used two shades or one or more as haze varied.
19	21¾	2½W.	230·9	322 42	Power 670. Through cloud. Two blue shades used. Star very bright and diffused. Strong N.E. wind.

Date 1901. G.M.T.	Hour Angle.	Day from Beginning of the Year.	Position Angle.	Remarks.
d h			° ′	
Aug. 20 22¼	3¼W.	231·9	319 32	Powers 670 and 1120. Thin cloud. Two blue shades used. Definition not very good. Star diffused, generally with moments of better seeing. Measures of distance give 0″·078.
21 22½	3½W.	232·9	316 0	Powers 670 and 1120. Two blue shades used. Taken during lulls of wind. Definition at times very good.
Sept. 1 21½	3 W.	243·9	279 27	Powers 670 and 1120. Blue and green shades used. Through thin cloud. Definition varying. Measures of distance gave 0″·09.
Observer ...	...	...	...	Mr. Bowyer.
Jan. 2 7½	3¾E.	1·3	45 3	Powers 670 and 1120. Sky very hazy. Definition fair. Rings visible occasionally. Measures easier than December 29.
15 6¾	2¾E.	14·3	18 8	Powers 670 and 1120. Measures made with and without blue shade. Definition fair. Several rings visible occasionally. Image rather diffused with high power.
18 6¾	2¼E.	17·3	11 0	Powers 670 and 1120. Definition fair, but image unsteady. Measures made with and without blue shade. Elongation seemed rather more apparent. Measures easier than for κ Pegasi.
Mar. 11 10¼	4½W.	69·4	176 2	Powers 670 and 1120. Measured through clouds when star appeared of about 8½ mag. Definition very fair at first, but as clouds became thicker definition got much worse.
Apr. 12 7½	3¾W.	101·3	53 9	Power 670. Measures made in twilight during short intervals of fair definition. Elongation very slight.

Σ 484 *and* Σ 485, *and Two Pairs.* By the Rev. T. E. Espin, M.A.

This fine group forms cluster H VII. 47. Mr. Holmes has given a drawing of it in the *English Mechanic*, 1901 December 27, and calls attention to the fact that there are several *comites* to Σ 485, and a pair similar to Σ 484 following. Two of the *comites*, D and E, had been previously seen and measured by Dembowski. Of the other *comites* F is fainter than either of Dembowski's, and the other two are more distant. When examining the group on January 17 with the 17¼-inch reflector a much nearer and more

difficult *comes* than any of these was suspected, and on January 28 and on subsequent nights it was seen and measured, but with great difficulty. The following are the previous results of the measures of this group, together with my own recent measures, which are, in general, the means of three nights' observations.

	Epoch.	Position Angle.	Distance.	Observer.
		°	″	
AB (Espin)	1902·09	257·0	5·43	Espin.
AC (Σ 485)	1830·24	303·32	17·98	Σ.
	1867·32	303·07	17·89	De.
	1902·09	303 30	17·45	Espin.
CD (Demb.)	1867·10	85·10	...	De.
	1902·10	84·75	14·15	Espin.
CE (Demb.)	1867·68	333·65	19·86	De.
	1902·09	333·07	18·87	Espin.
A^1B^1 (Σ 484)	1830·87	132·42	5·42	Σ.
	1867·32	130·80	5·38	De.
	1902·09	133·55	...	Espin.
A^1C^1	1830·87	244·05	48·96	Σ.
	1867·32	244·23	48·99	De.
	1902·11	244·7	48·8	Espin.
AF (Holmes)	1902·09	129·4	13·95	Espin.
A^2B^2 (Holmes)	1902·07	216·0	5·65	Espin.
CA^1	1902·11	244·7	48·8	Espin.
AA^2	1902·07	71·2	89·9	Espin.

I make the magnitudes as follows: A = 6·0; B = 12·0; C = 6·1; D = 10·8; D = 11·0; F = 11·5; A^2 = 9·5; B^2 = 10·5. Of Mr. Holmes's other two *comites* one is more distant than D in the same quadrant, and the other is about 10″ from E.

A comparison of the measures of the brighter stars shows that there is no motion within the group so far, and it would be interesting to know if a proper motion can be found for either of these stars.

In the course of the observations two pairs were found and measured:—

No. 1 B.D. +62°·640 R.A. $3^h\ 51^m\ 27^s$ Decl. +62° 10′·3 (1880).

			Mags.		
AB	P 221°·3	D 1″·48	8·2	8·5	1902·079
	220·3	1·48	8·2	8·6	·115
AC	169·7	8·2		10·5	·079
	169·4	8·6			·115

[A letter received since the above was written informs me that the pair No. 1 had been previously detected by Bird, and has been measured by Doolittle.]

No. 2 B.D. +61°·666 R.A. $3^h\ 55^m\ 19^s$, Decl. +61° 50′·5 (1880).

			Mags.	
AB	P 247°·5	D 4″·9	8·6 10·0	1902·079
	249·9	5·1	8·5 11·0	·112

The first is marked " Dupl ? " in the zones of the Astronomische Gesellschaft.

[*Note added by Mr. Lewis.*]

The two principal stars in this group are *Lalande* 7430 and 7433. The following are the places, brought up to 1890, from various catalogues :

		R.A. Lalande 7430. h m s	R.A. Lalande 7433. h m s
Lalande	1800	3 58 8·302	3 58 10·392
Oeltz. Arg. (N)	1842	8·301	10·101
Radcliffe	1845	8·176	10·576
Brussels	1865	8·122	10·322
Romberg	1878	8·227	10·297
Helsingfors	1881	8·227	10·377
Greenwich	1895	8·102	10·228

		N.P.D. Lalande 7430. ° ′ ″	N.P.D. Lalande 7433. ° ′ ″
Lalande	1800	27 57 52·1	27 58 4·1
Oeltz. Arg. (N)	1842	58·07	8·0
Radcliffe	1845	58·0	7·5
Brussels	1872	59·46	9·44
Romberg	1878	58·95	8·25
Helsingfors	1881	57·85	6·95
Greenwich	1890	59·52	9·45

These places are few and very precarious, and as the micrometer measures show no change it is fair to combine the two stars. The mean seconds for R.A. and N.P.D. 1890 are these :

	R.A. s	N.P.D. ″
Lalande	9 348	58·10
Oeltz. Arg.	·201	63·07
Radcliffe	·376	62·75
Brussels	·222	64·45
Romberg	·262	63·60
Helsingfors	·304	62·40
Greenwich	·165	64·49

results from which it is unsafe to deduce any proper motion. No systematic corrections have been applied.

Micrometrical and Visual Observations of Nova Cygni (1876) *made with the 40-inch Refractor of the Yerkes Observatory.*

By E. E. Barnard.

On the evening of 1876 November 24, at $5^h\ 45^m$, Schmidt at Athens discovered a brilliant star of the 3rd magnitude in *Cygnus* where a few days previous none such had existed. It rapidly faded, and by December 15 had ceased to be visible to the naked eye. The period of visibility without the telescope, therefore, did not extend over more than twenty-two days.

The most rapid decline in its light occurred between 1876 November 27 and November 29, when, according to Schmidt, in less than two days it faded through nearly 1½ magnitude. From then on until it ceased to be visible to the naked eye the decline was slow and gradual at about 0·13 magnitude a day. By 1877 February 1 it had reached 7·5 magnitude. By 1877 September 1 it had declined to the 10th magnitude, at which brightness it remained for nearly a year. Throughout 1880 and the first part of 1881 it remained constant at slightly less than 12 magnitude. On 1882 March 24 the Dun Echt observers estimated it to be of the 14th magnitude. There seem to be no other observations to verify this last estimation. Nearly ten years later (July 31, 1891) Professor Burnham examined the star with the 36-inch of the Lick Observatory and estimated it to be 13·5 magnitude. He found it a little brighter than the star No. 50, which he estimated to be 14 magnitude. I have not found any later observations of the star.

At the observations in 1891 (*Pub. L. O.*, vol. ii., p. 179), Professor Burnham says: "At times the new star did not seem to have a perfectly stellar appearance under moderately high powers, but rather to resemble an exceedingly minute nebula. This appearance, however, may not be real. The star is too faint to allow one to decide a question of this kind with any certainty. I did not make any measures from surrounding stars, as that has been very thoroughly done by the authors of the paper referred to [Copeland and Lohse: *Copernicus*, vol. ii., 101]."

Fearing the possible total disappearance of the *Nova*, Copeland and Lohse made an extensive series of measures of its position with respect to 112 surrounding stars. These observers state in *Copernicus*, vol. ii.: "Towards the end of 1877 October *Nova Cygni* had decreased still further in brightness, and so pointed to the possibility that it might eventually fade altogether from view. In the event of such a contingency it seemed very desirable to possess a map of the small stars in the immediate neighbourhood; accordingly measures in position-angle and distance from the new star to surrounding objects were commenced on October 29 and added to as occasion offered, until the whole series of measures extended to 38 nights, the last being 1882

March 24. The resulting map includes every star fairly measurable with the Dun Echt refractor of 15·06 inches aperture within 7½′ of *Nova Cygni*. . . . In this place it may be well to particularise a very small star, probably about the 15th magnitude, at a distance of 19″·1, in position-angle 314°·2 from *Nova*, as in a superficial examination it might possibly be confounded with the new star in the event of the total disappearance of the latter."

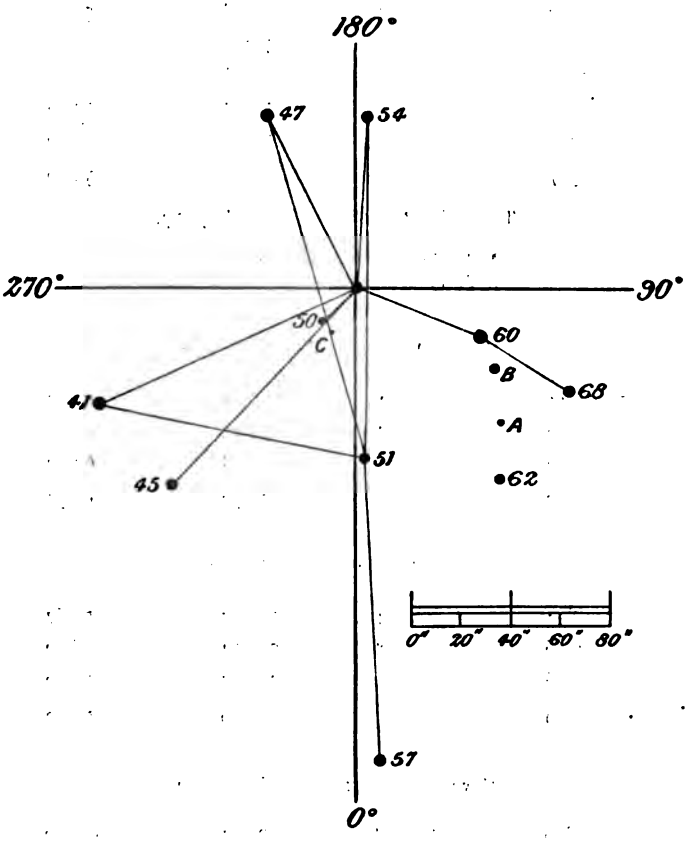
These measures and a most excellent map of 113 stars (including the *Nova*) are printed in *Copernicus*, Nos. 18 and 19, for 1882 June and July, for a copy of which I am greatly indebted to Dr. Ralph Copeland, Astronomer Royal for Scotland. The positions of these stars are reduced to the epoch 1878·0. I am also indebted to Dr. See for copies of the chart and of some of the measures in *Copernicus* from the library of the U.S. Naval Observatory.

To see if any change has occurred in the place of the new star in the past quarter of a century, I have selected a few of these stars for re-measurement along with the *Nova*. The re-measurement of all the stars observed at Dun Echt would be an unnecessary piece of labour, I therefore selected those stars near the *Nova* and which were within about two minutes of arc from it.

When I first looked up this object, on 1901 October 21, I adopted Schmidt's position of it given in *Ast. Nach.*, Bd. 89, p. 10, not having any chart by which to identify its place. Unfortunately Schmidt's position was in error (corrected later on in *A. N.*). Singularly enough the erroneous place coincided to within one second of time and a few seconds of arc, with a 15^m star (No. 51) which I observed that night and the next for the *Nova*. Upon deducing the place of this star from the observed $\Delta\alpha$ and $\Delta\delta$ and comparing it with the meridian positions obtained at Berlin (*A. N.* 2113, Bd. 89, p. 14), it was seen that the wrong star had been observed. This accounts for the measures of No. 51 on October 21 and 22. For the sake of accuracy I have since added one more night's measures to these stars. After this the *Nova* was easily identified.

I have charted the stars measured here with the 40-inch, and as a ready means of identifying the various measures at a glance I have not only added the numbers of the stars, but have also indicated the measures by lines connecting the various stars. Thus at a glance, without having resort to the actual measures, one can identify any star without trouble. It is to be regretted that diagrams of this kind are so often printed without any means of identifying any individual star without recourse to the measures and a protractor. Often I have been confused and uncertain in picking out the stars on such diagrams, without having a protractor immediately at hand to indicate the angles. In the chart in *Copernicus* of *Nova Cygni* this is not so bad, because the coordinates are printed on the map. But even here the identification of the individual stars would be much facilitated by numbering them on the chart. With such charts as I mention

it is an easy matter to identify the corresponding stars in the sky. But you still do not know the number of this or that particular star in the list of measures. If it happens to be at the telescope that a particular star on the chart is wanted to be identified by its number, as is frequently the case, it becomes very annoying and is the source of the loss of much time. I have, therefore, gone to the trouble of identifying the stars on such charts by scale and protractor, and numbering them to save time and confusion.



On the present chart the numbers are those assigned the stars at Dun Echt.

I have inserted four additional stars besides those measured. The star A is very faint = 16½ magnitude. B is of the same brightness as 62, while C, the very faint star mentioned near 50,

is extremely difficult under not very fair conditions. The star 62 has been inserted because of the comparisons of the light of the *Nova* with it.

Following are the measures :—

Micrometer Measures of Stars near Nova Cygni (1876).

Nova and No. 60. Magnitude 11·4.

		°	″
1901·844	Nov. 4	70·15	52·53
·846	5	70·48	53·10
·866	12	70·51	52·66*
·926	Dec. 4	70·58	52·47†
·961	17	70·25	53·06
·997	30	70·05	52·96
1901·907		70·34	52·80

These give $\Delta\alpha = 0^m\ 4^s{\cdot}488$, $\Delta\delta$ 0′ 17″·77.

* Single distances; clouds.
† Two single distances; clouds.

Nova and No. 54. Magnitude 12·1.

		°	″
1901·844	Nov. 4	175·27	67·83
·846	5	175·94	68·08
·926	Dec. 4	175·88	67·82
1901·872		175·70	67·91

Nova and No. 47. Magnitude 12·2.

		°	″
1901·844	Nov. 4	206·27	76·67
·846	5	206·04	76·49
·826	Dec. 4	206·27	76·39
1901·839		206·19	76·52

Nova and No. 41. Magnitude 13·2.

		°	″
1901·846	Nov. 5	294·01	110·09
·866	12	294·46	...*
·926	Dec. 4	294·01	110·02
·994	29	294·13	110·05
1901·908		294·15	110·05

* Clouds prevented distance measures.

Nova and No. 50. Magnitude 16·0.

1901·926	Dec. 4	312°·97	19″·38*
·961	17	315·54	20·09
·997	30	316·05	19·87
1901·961		314·86	19·78

* There is a 16^{m}·8 star close north of 50.

Nova and No. 45. Magnitude 13·7.

1901·961	Dec. 17	316°·28	106″·17
·994	29	316·28	106·05
1902·005	Jan. 2	316·21	105·80
1901·987		316·26	106·01

Nova and No. 51. Magnitude 15·3.

1901·844	Nov. 4	2°·48	66″·60
·846	5	2·34	66·68
·882	18	2·32	66·64
·926	Dec. 4	2·11	66·71
1901·875		2·31	66·66

These give $\Delta\alpha = 0^{m}\ 0^{s}\cdot243$, $\Delta\delta = 1'\ 6''\cdot61$.

Positions of Stars with reference to No. 51.

No. 51 and No. 57. Magnitude of No. 57, 12·0.

1901·808	Oct. 22	2°·62	116″·83
1902·033	Jan. 12	2·57	117·07
·035	13	2·55	117·21
1901·959		2·58	117·04

No. 51 and No. 60.

1901·808	Oct. 22	135°·52	67″·98
1902·033	Jan. 12	135·35	68·19
1901·920		135·43	68·08

These give $\Delta\alpha = 0^{m}\ 4^{s}\cdot378$, $\Delta\delta = 0'\ 47''\cdot78$.

No. 51 and No. 54.

1901·808	Oct. 22	178°·92	133″·86
1902·033	Jan. 12	178·84	134·24
1901·920		178·88	134·05

No. 51 and No. 47.

1901·808	Oct. 22	195°·08	140″·18
1902·033	Jan. 12	194·64	140·17
1901·920		194·86	140·18

No. 51 and No. 41.

1901·808	Oct. 22	258°·20	105″·21
1902·033	Jan. 12	257·90	105·21
1901·920		258·05	105·21

No. 60 and No. 68. Magnitude of No. 68 = 13·5.

1902·071	Jan. 26	57°·62	31″·84
·074	27	57·77	31·73
1902·073		57·69	31·78

In general the magnifying power used was 460, but some of the measures were made with 700 diameters.

Following are comparisons of these measures with those made at Dun Echt in 1877–82 :—

Nova and No. 41.

Dun Echt	293°·4	108″·6
Yerkes	294·1	110·1
D. E. – Y.	= −0·7	−1·5

Nova and No. 45.

Dun Echt	315°·0	107″·9
Yerkes	316·3	106·0
D. E. – Y.	−1·3	+1·9

Nova and No. 47.

Dun Echt	206°·2	78″·2
Yerkes	206·2	76·5
D. E. – Y.	0·0	+1·7

Nova and No. 50.

Dun Echt	314°·2	19″·1
Yerkes	314·9	19·8
D. E. – Y.	−0·7	−0·7

Nova and No. 51.

Dun Echt	358°·5	63″·7
Yerkes	362·3	66·7
D. E. – Y.	−3·8	−3·0

Nova and No. 60.

Dun Echt	69°·7	55″·2
Yerkes	70·3	52·8
D. E. – Y	−0·6	+2·4

No correction has been applied to the angles for precession.

These discrepancies are rather large. They do not seem to be due to any systematic errors nor to motion in the *Nova*. It is scarcely probable that they are due to motion in any of these small stars themselves.

The Dun Echt observers state, in *Copernicus* Nos. 18–19, p. 117, that "the probable error of one of the places is about ±1″·1 in either coordinate; this quantity is disappointingly large, but is probably to be ascribed in some measure to two special causes—the peculiar light of the *Nova*, which threw its image out of focus, and the fact that the settings could not all be made in the centre of the apparent field of view." The magnifying power used at Dun Echt was nearly always 229.

The star No. 60 is the one mentioned by Schmidt as a companion to the *Nova*, of the 12–13^m, 4^s·25 fol. and 15″·5 north. Schmidt's position was determined from two transits of a ring micrometer, and are not very exact (*A. N.* 2122, Bd. 89, p. 159).

Following are the observations for the position of the *Nova*, made with respect to the stars Bonn A. G. Cat. 15868 (D.M. +42°·4184) and 15876 (D.M. +42°·4185) :—

Observed Δα and Measured Δδ.

No. 51 and D.M. +42°·4184.

			m s		′ ″
1901·805	Oct. 21	Δα	0 24·51 (10)	Δδ	2 20·41 (2)
·808	22		0 24·50 (14)		2 20·92 (3)
1901·806			24·50 (28)		2 20·71 (5)

No. 51 is north preceding.

No. 51 and D.M. +42°·4185.

			m s		′ ″
1901·805	Oct. 21	Δα	0 34·96 (10)	Δδ	0 9·10 (2)
·808	22		0 34·90 (14)		0 9·67 (4)
1901·806			0 34·92 (28)		0 9·48 (6)

No. 51 is south preceding.

No. 60 and D.M. +42°·4185.

1901·808	Oct. 22	$\Delta\alpha$ m s ...	$\Delta\delta$	′ ″ 0 57·96 (2)
·827	29	0 30·65 (8)		0 58·01 (1)
1901·817		0 30·65 (8)		0 57·98 (3)

No. 60 is south preceding.

No. 60 and D.M. +42°·4184.

1901·827	Oct. 29	$\Delta\alpha$ 0m 20s·25 (8)	$\Delta\delta$ 1′ 32″·04 (2)

No. 60 is north preceding.

No. 51 and No. 60.

1901·805	Oct. 21	$\Delta\alpha$ 0′ 47″·50 (2)	$\Delta\delta$ 0′ 48″·42 (2)

$\frac{1}{15}$ sec δ (= 4s·29).

No. 51 is north preceding No. 60.

Nova and No. 60.

1901·827	$\Delta\alpha$ 0′ 51″·00 (4)	$\Delta\delta$ 0′ 17″·78 (5)

$\frac{1}{15}$ sec δ (= 4s·60) reject.

Nova is south preceding No. 60.

At the observations for $\Delta\alpha$ *Nova* was very difficult, and the measures should be rejected.

All the measures have been corrected for refraction.

As the comparisons with the Dun Echt measures do not seem to indicate with any certainty any motion in the *Nova*, it has occurred to me that this question might be settled by the comparisons of some of the stars and the *Nova* with the two D.M. stars following the new star, which have been observed on the meridian, and with the meridian observations of the *Nova* itself made some twenty-five years ago.

This investigation follows.

The star D.M. +42°·4184 has been observed at Bonn, Dun Echt, and Greenwich. These positions brought up to 1901·0 are in fair accord—

D.M. +42°·4184.

1901·0	α	h m s 21 38 14·24	δ = +42 ° ′ ″ 22 10·54	Bonn Beob.
		21 38 14·41	42 22 11·08	Bonn A.G. Cat.
		21 38 14·41	42 22 10·48	Greenwich and Dun Echt.
1901·0	α =	21 38 14·38	δ = +42 22 10·65	

Equal weight is given in these to the different observatories.

The star D.M. +42°·4185 has been observed at Bonn.

1901·0 $21^h\ 38^m\ 24^s{\cdot}60$ $+42°\ 24'\ 39''{\cdot}5$ Bonn A.G. Cat

From the first of these stars (42°·4184) we get the following position for star 51 from the observed $\Delta\alpha$ and $\Delta\delta$.

Star 51 1901·0 $\alpha = 21^h\ 37^m\ 49^s{\cdot}88$ $\delta = +42°\ 24'\ 31''{\cdot}36$ (A)

And this, with the observed position-angle and distance, gives the following position :

Nova 1901·0 $\alpha = 21^h\ 37^m\ 49^s{\cdot}67$ $\delta = +42°\ 23'\ 24''{\cdot}70$ (1)

From the same star (42°·4184) the following position of No. 60 is obtained from the observed differences of α and δ :

Star 60 1901·0 $\alpha = 21^h\ 37^m\ 54^s{\cdot}13$ $\delta = +42°\ 23'\ 42''{\cdot}69$ (a)

From the position-angle and distance this gives for the

Nova 1901·0 $\alpha = 21^h\ 37^m\ 49^s{\cdot}64$ $\delta = +42°\ 23'\ 24''{\cdot}92$ (2)

From the second star (42°·4185) we similarly deduce the following position of

No. 51 1901·0 $\alpha = 21^h\ 37^m\ 49^s{\cdot}67$ $\delta = +42°\ 24'\ 30''{\cdot}12$ (B)

From which the position of the *Nova* is derived as before.

Nova 1901·0 $\alpha = 21^h\ 37^m\ 49^s{\cdot}43$ $\delta = +42°\ 23'\ 23''{\cdot}51$ (3)

This star (42°·4185) also gives the place of

No. 60 1901·0 $\alpha = 21^h\ 37^m\ 53^s{\cdot}95$ $\delta = +42°\ 23'\ 41''{\cdot}52$ (b)

And this in turn gives for the *Nova* :

Nova 1901·0 $\alpha = 21^h\ 37^m\ 49^s{\cdot}46$ $\delta = +42°\ 23'\ 23''{\cdot}75$ (4)

Collecting these four positions of the *Nova* for 1901·0 we have

	h m s	° ′ ″
(1)	$\alpha = 21\ 37\ 49{\cdot}67$	$\delta = +42\ 23\ 24{\cdot}70$
(2)	$21\ 37\ 49{\cdot}64$	$42\ 23\ 24{\cdot}92$
(3)	$21\ 37\ 49{\cdot}43$	$42\ 23\ 23{\cdot}51$
(4)	$21\ 37\ 49{\cdot}46$	$42\ 23\ 23{\cdot}75$
1901·0	$\alpha = 21\ 37\ 49{\cdot}55$	$\delta = +42\ 23\ 24{\cdot}22$

The two first positions, depending on star 42°·4184, and the two last, on star 42°·4185, show a systematic difference amounting to $0^s{\cdot}2$ and $1''$ in α and δ respectively. This is perhaps due to motion in one or the other of the two stars.

Collecting the various meridian observations of the *Nova*, made when it was in its brighter stages, I find there were four observations. Bringing these up to 1901·0 we have

Positions of the Nova from Meridian Observations.

	h m s	° ′ ″	W.	
1901·0	α = 21 37 49·41	δ = +42 23 24·20	(2)	Vienna.
	21 37 49·47	42 23 23·98	(4)	Berlin.
	21 37 49·55	42 23 23·33	(5)	Greenwich.
	21 37 49·40	42 23 25·33	(1)	Dun Echt.
1901·0	α = 21 37 49·49	δ = +42 23 23·86		

The weights assigned there are from the number of observations. One of the observations at Vienna was given half weight, as it was observed under poor conditions.

Comparison of the mean of these positions with that of mine shows no certain change in the place of the *Nova*.

The agreement would be closer if we used the observations referred to 42°·4185 alone. As this last star place rests on nine observations it would seem that there has been a small change in the place of 42°·4184 and no change in that of the *Nova*.

The magnitudes I have assigned to the stars are the mean in each case of several estimates.

Following are comparisons of the magnitudes :—

Star 41.	m
Dun Echt	13·4
Yerkes	13·2
D. E. – Y.	+0·2

Star 49.	m
Dun Echt	14·7
Yerkes	14·0
D. E. – Y.	+0·7

Star 42.	
Dun Echt	15·0
Yerkes	14·0
D. E. – Y.	+1·0

Star 50.	
Dun Echt	15·0
Yerkes	16·0
D. E. – Y.	–1·0

Star 45.	
Dun Echt	14·4
Yerkes	13·7
D. E. – Y.	+0·7

Star 51.	
Dun Echt	14·3
Yerkes	15·3
D. E. – Y.	–1·0

Star 4 .	
Dun Echt	11·9
Yerkes	12·2
D. E. – Y.	–0·3

Star 54.	
Dun Echt	12·0
Yerkes	12·1
D. E. – Y.	–0·1

Star 57.		Star 68.	
Dun Echt	13·4	Dun Echt	14·0
Yerkes	12·0	Yerkes	13·2
D. E.−Y.	+1·4	D. E.−Y.	+0·8

Star 60.		Star 73.	
Dun Echt	11·0	Dun Echt	13·4
Yerkes	11·4	Yerkes	12·5
D. E.−Y.	−0·4	D. E.−Y.	+0·9

Collecting these differences of magnitude, we have :—

m	m
+0·2	−0·1
+1·0	+1·4
+0·7	−0·4
−0·3	+0·8
+0·7	+0·9
−1·0	D. E.−Y. = +0·2
−1·0	

The magnitudes of those stars which were not micrometrically measured by me should not have much weight, as they would not be so carefully estimated.

These discordances of magnitude are not very large, and no more than would be expected from different observers with different telescopes and such faint objects as some of these stars are.

It must be understood, however, that these estimates have been made under the most unfavourable conditions of seeing here, when a star anyways near the limit of the 40-inch would not be seen.

On several occasions I have seen a very faint star near No. 50 and north of it. It was too faint to measure—and there was no reason for measuring it.

By estimation, in terms of other distances and position-angles, this small star would be, with reference to No. 50, in

P. 20°± Dist. 5″±.

No. 50 is a faint star to have been measured at Dun Echt. There does not seem to have been any change in its brightness, though one would almost infer that it must have been brighter some twenty or twenty-five years ago.

It is difficult to estimate the brightness of the *Nova*. It seems to be more affected by bad seeing or moonlight than the small stars near it. This is another indication of its probable nebulous

character. My estimates of its relative light seemed to show that it varied through about ½ magnitude. This, I think, however, is due to its lack of exact definition and the effect of local conditions of moonlight or bad seeing, though I am not sure yet that there is not a fluctuation of its light.

Following are estimations of the brightness of the *Nova* with respect to the stars 50 and 51.

Comparisons of the Brightness of the Nova.

1901 Nov.	12	*Nova* = 51 and possibly slightly brighter.						
	18	,,	= 51.					
	19	,,	= $\frac{5}{10}^m$	less than	51.			
Dec.	4	,,	= $\frac{2}{10}^m$	,,	,,	$\frac{2}{10}^m$	brighter	than 50.
	17	,,	= $\frac{3}{10}^m$	,,	,,	$\frac{5}{10}^m$	,,	,,
	22	,,	= $\frac{5}{10}^m$	,,	,,	$\frac{1}{10}^m$	,,	,,
	29	,,	= 51	...	...	$\frac{5}{10}^m$	,,	,,

The following estimates are more carefully made and are believed to be more exact. They were made specially to decide the question of variability.

1901 Dec.	30	*Nova* $\frac{1}{10}^m$	less than	51	...	$\frac{4}{10}^m$	brighter	than 50.
1902 Jan.	2	midway between 50 and 51.						
	5	$\frac{3}{10}^m$	less than	51	...	$\frac{1}{10}^m$	,,	,,
	6	$\frac{3}{10}^m$	,,	,,	...	$\frac{5}{10}^m$	,,	,,
	7	$\frac{2}{10}^m$	,,	,,	...	$\frac{5}{10}^m$	,,	,,
	10	$\frac{2}{10}^m$	,,	,,	...	$\frac{4}{10}^m$	,,	,,
	11	$\frac{3}{10}^m$	,,	,,	..	$\frac{3}{10}^m$	,,	,,
	12	$\frac{3}{10}^m$	,,	,,	...	$\frac{3}{10}^m$	,,	,,
	13	$\frac{3}{10}^m$	,,	,,	...	$\frac{2}{10}^m$	,,	,,
	14	$\frac{2}{10}^m$	,,	,,	...	$\frac{4}{10}^m$	,,	,,
	18	$\frac{2}{10}^m$	,,	,,	...	$\frac{4}{10}^m$	,,	,,
	26	$\frac{2}{10}^m$	,,	,,	...	$\frac{4}{10}^m$	,,	,,
	27	$\frac{4}{10}^m$	,,	,,	...	$\frac{2}{10}^m$	,,	,,
Means		0·25				0·34		

These estimates do not seem to be decisive. It is rather probable though that, on account of the physical appearance of the *Nova*, these differences do not indicate variability. They may prove valuable, however, in the future in deciding any question of change.

With these, and the estimated magnitudes of stars 50 and 51,

the following two determinations of the present brightness of *Nova Cygni* result from star 50, $15^{m}\cdot7$, and from star 51, $15^{m}\cdot6$.

From ten nights' comparisons the star No. 62 was found to be equal to No. 50 (the mean gave $0^{m}\cdot03$ less than No. 50), while from eleven nights' estimates, No. 62 was found to be $0^{m}\cdot35$ less than the *Nova*.

Twelve nights' comparisons made No. 51 less than No. 68 by $0^{m}\cdot18$.

In all the estimates of brightness the eyes were placed parallel to the line joining the stars. This is very important in my case, for, as I have shown in *A. J.* 370, vol. xvi. p. 75, two stars that are equal when the line between them is parallel to my eyes, will differ by half a magnitude when they are in a vertical line; the lower one being always the brighter. Just what is the cause of this peculiarity is not clear, but it seems that it might be due to a dulling of a portion of the retina by the preponderance of the illumination of the sky in the daytime over that of the landscape, about one half of the retina usually receiving the light from the sky, while the other half receives that from the landscape. The lower star would therefore fall on that part of the retina usually occupied by the landscape, and hence on a more sensitive portion.

Mr. J. A. Parkhurst has kindly measured the relative light of Nos. 50 and 51 with the photometer on the 40-inch. The difference as determined by him is $0^{m}\cdot66$ from one night's observations under rather unfavourable conditions. This is a little larger than the difference that would be derived from my estimates with the *Nova* and these two stars, and agrees almost exactly with the difference of my estimates of the magnitudes ($0^{m}\cdot7$) of the two stars themselves.

The changes of colour in this star were not very remarkable. At the time of discovery by Schmidt it was of a strong golden yellow. This colour, according to Schmidt, it retained until it ceased to be visible to the naked eye—to him it was at no time of a decided orange tint, but yet of a full yellow. When observable only with the telescope some of the observers described it as red.

According to Dr. Copeland, at Dun Echt, the star presented a rather complicated spectrum during its brighter stages in 1876 and the beginning of 1877. On 1876 December 5, when its magnitude was 4·5, he found that one of the spectral lines coincided almost exactly with the brightest line of the gaseous nebulæ. Another line corresponded very nearly with one of the bright lines in the spectra of the Wolf-Rayet stars in *Cygnus*. In the next eight or nine months the spectrum was reduced to a single line with the merest traces of a continuous spectrum. The star itself was later described as having "a small disc with a soft margin;" the *Nova* seemingly having become a nebula, both visually and spectroscopically. In reference to this remarkable change in the physical condition of the star, Dr. Copeland says, in *A. N.* 2158:—"Bearing in mind the history of this star from

the time of its discovery by Schmidt, it would seem certain that we have an instance before us in which a star has changed into a planetary nebula of small angular diameter. At least it may be safely affirmed that no astronomer discovering the object in its present state would, after viewing it through a prism, hesitate to pronounce as to its present nebulous character."

One striking feature about *Nova Cygni* mentioned by the Dun Echt observers was the fact that there was a decided difference in the focal adjustment for it and a star. According to Dr. Copeland, with the 15-inch Grubb refractor, this amounted on 1877 October 2, when the star was about 10^m, to about 2 mm. (the focus being outside of that for a star). In this respect it resembled *Nova Aurigæ* rather than *Nova Persei* of the past year. There seems to be no record of anything of this kind in its earlier stages of brightness in 1876, and it probably showed no such peculiarity then.

So far as I can learn, *Nova Aurigæ* in its first appearance, when bright, did not show this peculiarity, nor even when faint in the spring of 1892. It was only at its second apparition that the effect became evident. At present *Nova Persei* has shown nothing of this kind. In all probability, however, it will show it later on when it has become much less bright. It is the intention to frequently test the focus to see when this effect first becomes visible—if it makes its appearance at all. Careful tests up to 1902 January 31 showed no sensible difference between its focus and that of a star.

On account of the faintness of *Nova Cygni* it is difficult now to measure its focus with reference to a star in the ordinary way. Under the best seeing, however, there is certainly a slight difference of focus to the extent of possibly $\frac{1}{10}$-inch outside of that for a star. Even when in best focus it does not appear to be perfectly sharp. It seems to be more or less ill-defined, resembling in this the present appearance of *Nova Aurigæ*. Of course no colour is ever discernible in so faint an object.

I have examined *Nova Coronæ* (1866) several times lately, but always under very bad conditions of seeing. Under those conditions no difference of focus was noticeable between it and a star—though I hope to investigate this point more carefully later on with better seeing.

I have mentioned the want of *Nova Persei* to show any peculiarity in its focus from that of a fixed star. There is another peculiarity which I believe is important, but which in the greater interest due to the photographic nebulosity about the *Nova* is lost sight of. In the *Astrophysical Journal* for 1901 October, vol. xiv. No. 3, attention is called to the peculiar appearance of the *Nova* in the 40-inch: "On August 12, the seeing was unusually good; examining the *Nova* with high powers I was struck with its appearance. It was brighter than the star [D.M. $+43°\cdot732$], but under high magnifying powers its light was strikingly dull, having more the appearance of planetary

light. This was so decided, that had I been examining the stars in that region I should at once have singled out the *Nova* as different from any of the stars. The spurious disc appeared much duller and somewhat larger than that of a star, and of a slight yellowish colour."

As the new star has faded, this peculiarity has become even more striking. The light of the *Nova*, which is greenish white, is very much like that of *Neptune*, and when *Neptune* is seen with a power that just begins to show its disc, the general likeness to the *Nova* would be striking. The light, however, is more greenish than that of *Neptune*. It also strongly resembles *Ceres* when that planet is seen with not too high a power. The colour is also like some of the planetary nebulæ—especially N.G.C. 7662 in *Andromeda*. While the light from a star is vivid, that of *Nova Persei* is singularly dull with high powers.

Yerkes Observatory, Williams Bay, Wisconsin:
1902 *February* 5.

On the Variation of S Carinæ. By Alex. W. Roberts, D.Sc.

There are at present (February 1902) between 160 and 180 stars south of $-30°$ dec., whose variation is known with some degree of certainty.

Of this number ten are of marked interest, as their variation was discovered and definite minima and maxima determined by Dr. Gould. The star *S Carinæ* (Ch. 3637) is one of these Cordoba variables. Inasmuch as I have already dealt with the variation of *R Carinæ* (*Monthly Notices*, vol. lxi. p. 552) and with the variation of *R Centauri* (*Monthly Notices*, vol. lxi. p. 355), both stars whose variation was discovered and defined by Dr. Gould, it will, I think, give a measure of completeness to these papers to consider also the variation of *S Carinæ*.

It may be noted here that the three stars are good examples of three well-defined types of long-period variation.

We consider in the first place the data which are of service as leading to a determination of the period of the star.

Dr. Gould's note on the variation of *S Carinæ* is as follows (*Uranometria Argentina*, p. 253):—

"The fluctuations of the light of this star appear to be within the limits $6\frac{1}{4}^m$ and a little above 9^m, and the length of its period to be several months. In 1872 its magnitude was observed as follows: T., May 26,* 7·0; April 3, 6·9; H., May 24, 30, 8·0; R., July 28, 7·9; Aug. 7, 7·4. In 1874 it was twice observed by Mr. Thome, May 21, 6·3; June 9, 7·3; observations which place the variability of the star beyond question.

* March 26?

"In May 1877 he estimated it as $8\frac{1}{4}^m$. Amid the great amount of other labour, sufficient observations have not been made to enable me to determine the light curve; but with the certainty of its variability I have not hesitated to designate it *S Carinæ*. Its colour is decidedly reddish."

Although Gould's observations are not sufficient to yield a period they are so situated on the light curve that they afford an indication of a definite date when the star passed through its maximum phase in 1872.

Later on in the present investigation this date will be determined and a period deduced from it. It is necessary first, however, to consider the more recent observations. These alone are sufficient to yield complete elements of variation, and thus they readily admit of being related to the Cordoba observations.

Observations of *S Carinæ* were begun at Lovedale in April 1891, and have been continued with one short interval down to the present. The number of observations secured during this period is close on 800. Nearly all the observations were made with a good 1-inch telescope, the usual precautions being taken to eliminate position error.

In the following two tables are given the several maxima and minima determined from the Lovedale observations. For purposes of computation the Julian day is given in the third column. In the fourth column is set forth the magnitude at maximum or minimum phase. In the last column is given the difference between these observed magnitudes and the mean magnitude for the whole series, viz. $6^m{\cdot}2$ for maximum and $8^m{\cdot}9$ for minimum.

TABLE I.

Determination of Maxima.

Rotation No.	Date.	Julian Day. J	Mag. m	Diff. m
1	1891 June 30	2411914	6·2	0·0
2	1892 April 17	2412206	5·8	−0·4
3	1893 Feb. 7	2412502	5·9	−0·3
4	June 30	2412645	5·9	−0·3
5	Nov. 30	2412798	6·0	−0·2
6	1894 May 9	2412958	6·6	+0·4
7	Sept. 27	2413099	6·0	−0·2
8	1895 July 21	2413396	5·7	−0·5
9	Dec. 28	2413556	6·7	+0·5
10	1896 May 21	2413701	6·0	−0·2
11	Oct. 16	2413849	5·8	−0·4
12	1898 Oct. 24	2414587	6·3	+0·1
13	1899 Mar. 28	2414742	6·6	+0·4
14	Aug. 20	2414887	6·3	+0·1

Rotation No.	Date.	Julian Day. J	Mag. m	Diff. m
15	1900 Jan. 24	2415044	6·6	+0·4
16	June 11	2415182	6·0	−0·2
17	Nov. 10	2415334	6·2	0·0
18	1901 April 7	2415482	6·4	+0·2
19	Aug. 29	2415626	5·8	−0·4
20	1902 Jan. 22	2415772	6·6	+0·4

TABLE II.

Determination of Minima.

Rotation No.	Date.	Julian Day. J	Mag. m	Diff. m
1	1892 Feb. 8	2412137	9·4	+0·5
2	July 6	2412286	9·2	+0·3
3	Nov. 19	2412422	8·8	−0·1
4	1893 May 3	2412587	9·0	+0·1
5	Sept. 20	2412727	8·7	−0·2
6	1894 Feb. 15	2412875	9·2	+0·3
7	July 15	2413025	9·3	+0·4
8	1895 May 13	2413327	8·7	−0·2
9	1896 Mar. 13	2413632	8·7	−0·2
10	Aug. 2	2413774	8·9	0·0
11	1898 Aug. 18	2414520	9·0	+0·1
12	1899 Jan. 9	2414664	8·9	0·0
13	June 8	2414814	8·9	0·0
14	Oct. 29	2414957	8·9	0·0
15	1900 Mar. 27	2415106	8·7	−0·2
16	Aug. 25	2415257	8·7	−0·2
17	1901 Jan. 24	2415409	8·7	−0·2
18	June 15	2415551	9·1	+0·2
19*	Nov. 19	2415708	9·3	+0·4

It is not necessary to give prominence to the minor details of this investigation, which has for its purpose the determination of the elements of *S Carinæ* from the foregoing data. Indeed it would be tedious to do so. I may therefore confine myself to a statement of the main points and results of the investigation.

(1) If the dates of maximum or minimum phase be grouped in sets of three years, and if a mean period be obtained from each of these sets, there will appear evidence that the period of the star is subject to secular variation

It would seem that the cycle is completed in about nineteen years, or forty-five light periods, although on this matter the evidence is far from conclusive, as it must of necessity be, from

the limited period during which systematic observations have been made.

(2) Let now the following values be considered :—

$P+\Delta p$ = period of variation.

$T_M+\Delta t_M$ = epoch of maximum phase.

$T_m+\Delta t_m$ = epoch of minimum phase.

E = number of light periods dating from epoch.

J_M = Julian day of observed maximum (Table I. col. 3).

J_m = Julian day of observed minimum (Table II. col. 3).

We may regard the secular variation of period to be of the character represented by the expression

$$\kappa \cos (\phi E - M).$$

As a first approximation we take,

$$\phi = 8^\circ ;$$

that is, the cycle of perturbations is completed in forty-five light periods.

It is evident that, with regard to maxima determinations (Table I.), the relation between the foregoing quantities is set forth by the equation :—

$$(T_M + \Delta t_M) + E(P + \Delta p) + \kappa \cos (8^\circ E - M) = J_M \quad . \quad . \quad (1)$$

Let now

$$x = \kappa \cos M$$
$$y = \kappa \sin M,$$

and equation (1) becomes for maxima determinations

$$\Delta t_M + E\Delta p + x \cos 8^\circ E + y \sin 8^\circ E = \{J_M - (T_M + EP)\} \quad (2)$$

and for minima determinations

$$\Delta t_m + E\Delta p + x \cos 8^\circ E + y \sin 8^\circ E = \{J_m - (T_m + EP)\} \quad (3)$$

Thirty-nine equations of condition, twenty for Table I. and nineteen for Table II., were constructed on this type, the following values being assumed :—

$$P = 149^d$$
$$T_M = 2415038^J$$
$$T_m = 2415112^J.$$

(3) It will suffice to state only the final results of the solution of the two sets of equations.

Maxima determinations.—A rigorous consideration of the twenty equations yielded the following values :—

$$\Delta p = -0^{d}\cdot29$$
$$\Delta t_M = -5\cdot57$$
$$x = +3\cdot74$$
$$y = -3\cdot56$$

that is,

$$P + \Delta p = 148^{d}\cdot71$$
$$T_M + \Delta t_M = 2415032^{J}\cdot4$$

Secular variation

$$= 5^{d}\cdot2 \cos (8° E - 316°\cdot3).$$

Minima determinations.—A similar but quite distinct solution of the nineteen equations (Table II.) yielded the following values :—

$$\Delta p = -0^{d}\cdot28$$
$$\Delta t_m = -4\cdot10$$
$$x = +1\cdot91$$
$$y = -3\cdot56$$

that is

$$P + \Delta p = 148^{d}\cdot72$$
$$T_m + \Delta t_m = 2415107^{J}\cdot9$$

Secular variation

$$= 4^{d}\cdot1 \cos (8° E - 331°\cdot7).$$

The close agreement between the results obtained from a separate consideration of the data in Table I. and the data in Table II. is strong presumptive evidence of the accuracy, not only of the value of the period obtained, but more especially of the amount and character of the secular variation.

Combining the two sets of results we have as the final and definitive values of the elements of *S Carinæ* :—

$$J_M = 2415032^{J}\cdot4 + E\,148^{d}\cdot72 + 4^{d}\cdot7 \cos (8° E - 324°)$$
$$M - m = 73^{d}\cdot2.$$

(4) In Tables III. and IV. is exhibited the amount of accordance between theory and observation.

The third column in both tables contains the observed dates

already given in Tables I. and II.; and the fourth column the dates computed from the elements just determined. The residuals are indicated in the last column.

TABLE III.

Maxima Observations.

Rotation No.	E.	Observed Date. J	Computed Date. J	O−C. d
1	−21	2411914·0	2411906·2	+7·8
2	19	2412206·0	2412204·6	+1·4
3	17	2412502·0	2412503·4	−1·4
4	16	2412645·0	2412652·8	−7·8
5	15	2412798·0	2412802·1	−4·1
6	14	2412958·0	2412951·4	+6·6
7	13	2413099·0	2413100·7	−1·7
8	11	2413396·0	2413399·4	−3·4
9	10	2413556·0	2413548·6	+7·4
10	9	2413701·0	2413697·7	+3·3
11	8	2413849·0	2413846·7	+2·3
12	3	2414587·0	2414590·8	−3·8
13	2	2414742·0	2414739·4	+2·6
14	− 1	2414887·0	2414887·8	−0·8
15	0	2415044·0	2415036·2	+7·8
16	+ 1	2415182·0	2415184·5	−2·5
17	2	2415334·0	2415332·7	+1·3
18	3	2415482·0	2415480·9	+1·1
19	4	2415626·0	2415629·0	−3·0
20	+ 5	2415772·0	2415777·1	−5·1

Mean residual $3^{d}\cdot8$

TABLE IV.

Minima Observations.

Rotation No.	E.	Observed Date. J	Computed Date. J	O−C. d
1	−20	2412137·0	2412130·9	+6·1
2	19	2412286·0	2412280·1	+5·9
3	18	2412422·0	2412429·4	−7·4
4	17	2412587·0	2412578·9	+8·1
5	16	2412727·0	2412728·3	−1·3

Rotation No.	E.	Observed Date. J	Computed Date. J	O—C. d
6	−15	2412875·0	2412877·6	−2·6
7	14	2413025·0	2413026·9	−1·9
8	12	2413327·0	2413325·6	+1·4
9	10	2413632·0	2413624·1	+7·9
10	9	2413774·0	2413773·2	+0·8
11	4	2414520·0	2414517·7	+2·3
12	3	2414664·0	2414666·3	−2·3
13	2	2414814·0	2414814·9	−0·9
14	− 1	2414957·0	2414963·3	−6·3
15	0	2415106·0	2415111·7	−5·7
16	+ 1	2415257·0	2415260·0	−3·0
17	2	2415409·0	2415408·2	+0·8
18	3	2415551·0	2415556·4	−5·4
19	+ 4	2415708·0	2415704·5	+3·5

Mean residual $3^d·7$.

(5) In Tables I. and II. is given the libration on either side of the mean magnitude at maximum and minimum phase.

There was some expectation that this libration would, after the manner of the inequalities in period, follow some regular law.

It is evident, however, that the residuals given in the last column of Tables I. and II. are not systematic in their character; or, at any rate, there is so little evidence of systematic discordance that we may safely assume that it does not exist.

(6) It is pertinent to this investigation to relate the Cordoba observations of *S Carinæ* to those made at Lovedale.

Dr. Gould's observations are as follows :—

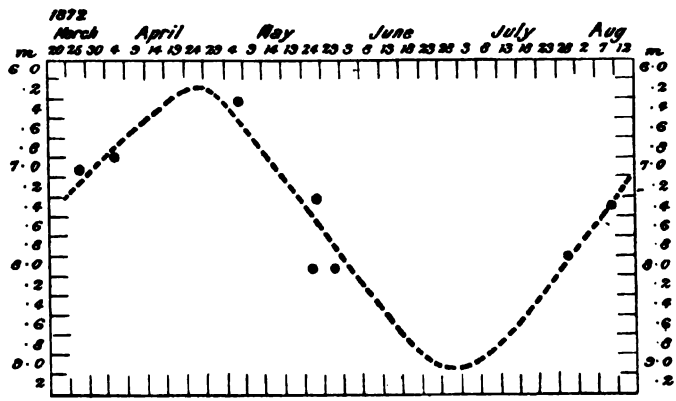
Observed Date.	Reduced Date.	Mag.
1872 Mar. 26	1872 Mar. 26	7·0
April 3	April 3	6 9
May 24	May 24	8·0
„ 30	„ 30	8·0
July 28	July 28	7·9
Aug. 7	Aug. 7	7·4
1874 May 21	May 6	6·3
June 9	„ 25	7·3

In the second column of the above table are given the dates of the first column reduced to one mean light period, that of March to August 1872.

Placed in order of time sequence, these observations are :—

	1872.	Mag.
1	Mar. 26	7·0
2	April 3	6·9
3	May 6	6·3
4	„ 24	8·0
5	„ 25	7·3
6	„ 30	8·0
7	July 28	7·9
8	Aug. 7	7·4

It is evident from the following chart that these eight observations indicate a maximum of $6^{m}\cdot2$ on or about 1872 April 24, and a mimimum of $9^{m}\cdot0$ on 1872 July 1.



Thus we have for an auxiliary determination of period :—

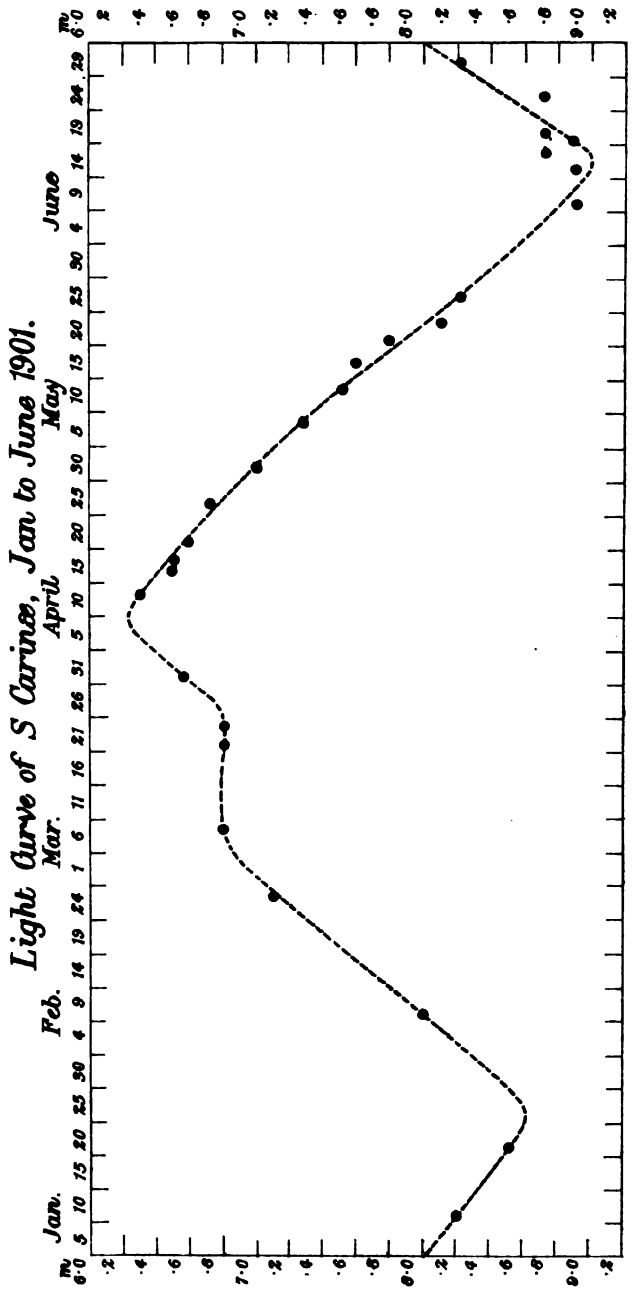
Maximum Phase.

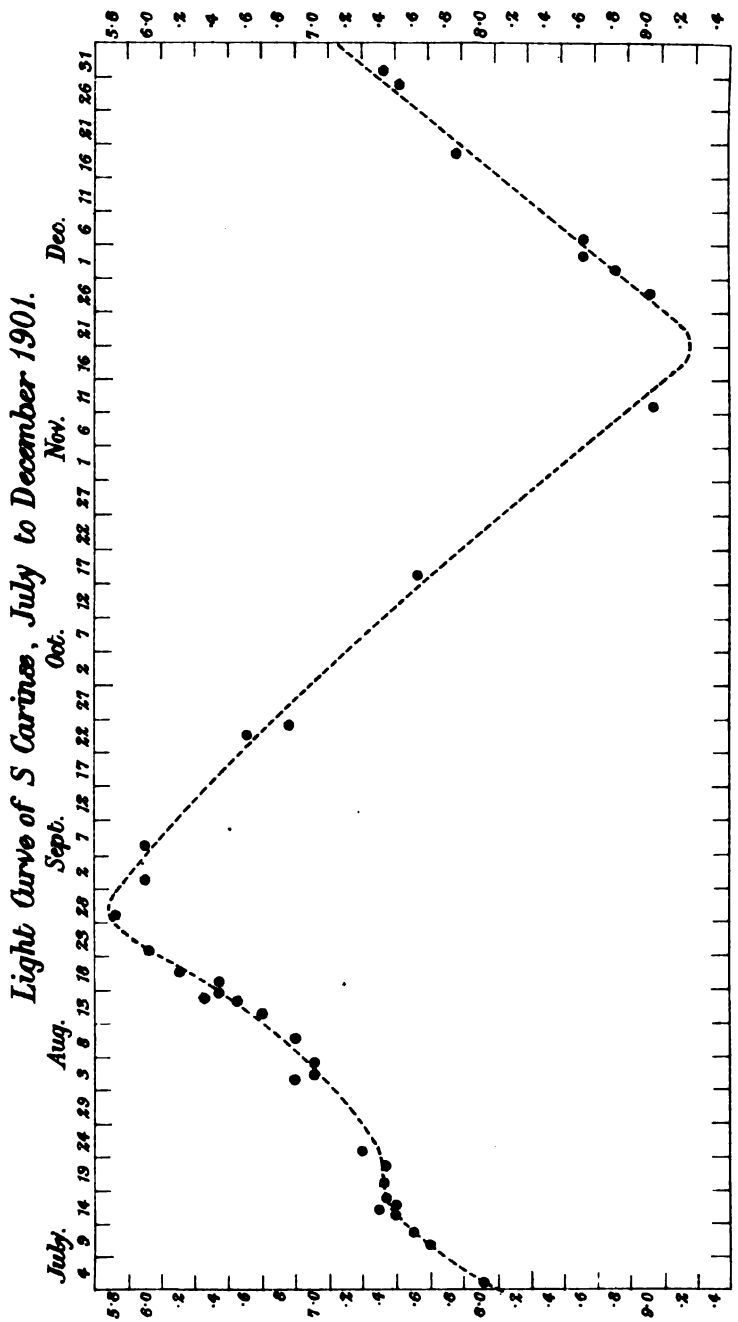
		d.
Cordoba observations,	1872 April 24	= 2404910·0
Lovedale observations,	1900 Jan. 12·4	= 2415032·4
	Interval	= 10122·4

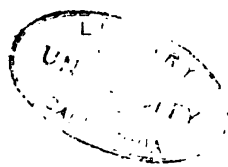
Minimum Phase.

		d.
Cordoba observations,	1872 July 1	= 2404976·0
Lovedale observations,	1900 March 28	= 2415107·9
	Interval	= 10131·9

If we take the mean interval between the Cordoba and the


Light Curve of S Carinæ, Jan to June 1901.
Jan.
Feb.
Mar.
April
May
June
m
6·0
7·0
8·0
9·0


Light Curve of S Carinæ, July to December 1901.
July.
Aug.
Sept.
Oct.
Nov.
Dec.



Lovedale mean light curves as 10127 days, we find that sixty-eight periods are performed in this time, giving a mean period of

$$148^{d}\cdot9.$$

This value is in satisfactory agreement with that found from Lovedale observations alone, viz.

$$148^{d}\cdot72.$$

If we take a mean between these two values we shall arrive at a value of the period correct to within one-tenth of a day.

(7) In plates 9 and 10 are represented graphically the light changes of *S Carinæ* during the year 1901.

The main characteristics of the light curve are (1) the practically equal duration of the increasing and decreasing phases, and (2) the indistinct secondary maximum which takes place about forty days before primary maximum.

With regard to the equality that exists between decreasing and increasing phases, the numerical values are:—

	d.
Increasing phase	73·2
Decreasing phase	75·5
Difference	2·3

It has been shown that a similar tendency to equality between increasing and decreasing phase exists in the case of the long period *T Centauri* (*Monthly Notices*, vol. lxii. p. 69).

In this case the values are :—

	d.
Increasing phase	44·1
Decreasing phase	46·5
Difference	2·4

In neither of these instances, therefore, is a rapid ascent to maximum a feature of the star's variation. Similar instances could be multiplied, but these two definite determinations are sufficient to form an exception of some weight to the view which sometimes prevails that in all cases of long period variation the rise to maximum is very much more rapid than the fall to minimum.

The secondary maximum, which is of a very rudimentary character, is sometimes entirely absent. In one of the 1901 light curves there is only slight evidence of its existence. The phenomenon is therefore irregular in its nature.

Apart from this exception, however, all the other features of variation of *S Carinæ* are of marked regularity. Its return to maximum or minimum can be predicted within a few days; its limits of variation are subject to no erratic fluctuations, and there

is a certain general conformity to a common type of variation in all the light curves.

This common type is indicated in the plates which accompany this paper.

Lovedale: 1902 *February* 1.

New Variable Stars found during the Measurements for the Astrographic Catalogue at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

In the course of the measurement of the plates for the photographic map of the heavens, under Mr. Hollis's direction, a careful note is made of large differences of diameter of images of the same star on the overlapping plates which are measured simultaneously in the duplex micrometer.

The following four stars were in this way found to be variable, and their diameter on other plates were measured; the variability of the third one was announced by Dr. Anderson in 1897. The other three appear to be new :—

		Approx. R.A. 1900. h m s	Approx. Dec. 1900. ° ′
A	... ...	18 5 9	65 56·9
B	... ...	18 6 54	66 8·9
C	U Draconis ...	19 9 42	67 7·1
D	... ...	5 49 22	74 30·8

A and B occur on the same plates; the following table gives their measured diameter (the unit being 0″·15) and that of neighbouring comparison stars whose magnitudes are taken from the *Bonn Durchmusterung* :—

No. of Plate.	Date.	Exp. m	A	B	66°·1074 9·0	65°·1238 9·5	66°·1083 9·4	66°·1079 9·5
411	1892 June 6	40	44	42	...	42	47	42
441	1892 „ 23	6	22	16	24	22	22	16
2117	1894 July 3	40	52	10	52	51	44	32
2688	1895 June 16	6	0	3	32	22	24	16
2697	1895 „ 17	6	0	0	...	25	22	13
2724	1895 „ 25	40	0	10	52	40	44	30
5088	1900 Sept. 13	6	16	0	22	22	22	20
5658	1901 June 6	40	21	3	41	33	38	26

A shows on these photographs changes of magnitude from nearly $9^{m}\cdot0$ to below the limit reached by chart plates of 40^{m} exposure or a nominal $14^{m}\cdot0$.

B shows almost as great a range, as it varies from $9^{m}\cdot5$ of the B. D. to nearly the limit of the chart plates.

The following table shows the variation of C (*U Draconis*) as shown by the measures of diameter :—

No of Plate.	Date.	Exp. m	C	67°1118 8·9	67°1120 9·2	67°1113 9·5
483	1892 Aug. 5	40	60	70	58	56
1380	1893 „ 19	6	18	46	38	39
1381	1893 „ 19	40	40	82	68	58
2136	1894 July 11	6	0	44	39	35
2288	1894 Oct. 16	6	4	33	32	19
3200	1896 July 12	40	3	80	64	52
5666	1901 „ 8	6	10	54	44	36

These measures show that C was only a little below $9^{m}\cdot0$ on 1892 August 5, and 1896 July 12 was only just shown on a chart plate of 40^{m} exposure.

The following table shows in a similar manner the variations in magnitude of D :—

No. of Plate.	Date.	Exp. m	D	74°275 8·1	74°267 8·2	74°272 9·3	74°266 9·5
3796	1897 Dec. 24	40	38	123	94	92	58
3869	1898 Feb. 23	40	20	103	84	78	62
3886	1898 Mar. 2	6	0	58	42	42	24
4302	1899 Feb. 25	6	40	54	42	34	22
5410	1901 Feb. 11	40	0	80	66	60	44

The above measures show that this star was between the 8th and 9th magnitudes on 1899 February 25, and on 1901 February 11 was below the limit of the chart plates.

The Magnitude of η Argûs 1900–1902. By R. T. A. Innes.

The two comparison stars used are given in the *Monthly Notices*, vol. lix. p. 570.

	Mag.	Colour.	Means. Date.	Mag.	Colour.
1900 Feb. 26	7·7	6			
Mar. 31	7·65	6	1900·3	7·68	6·3
June 8	7·7	7			

		Mag.	Colour.	Means. Date.	Mag.	Colour.
1901 Jan.	21	7·9	7			
Mar.	22	7·7	6·5	1901·3	7·78	6·8
June	8	7·75	7			
1902 Jan.	26	7·7	6·5			
Feb.	1	7·65	6·5	1902·1	7·72	6·5
	8	7·8	6·5			

Telescope, 7-in. Merz equatorial, as before.

Royal Observatory Cape of Good Hope:
1902 *February* 10.

Note on Professor Turner's Recent Paper on Photographic Surveying. By H. G. Fourcade.

(*Communicated by Sir David Gill.*)

In the *Monthly Notices* for December 1901 there appears a paper by Professor Turner, F.R.S., on "A Simple Method of Accurate Surveying with an Ordinary Camera."

The first method noticed by Professor Turner, in which a pair of views is taken at right angles to a base line, has, in its simple form, been used by me for some years, and, improved in respect of speed, convenience, and accuracy by the proposed adoption of a stereoscopic measuring instrument combining some of the features of stereoscopic range-finders and measuring machines for stellar photographs, it is described in a paper read before the South African Philosophical Society on October 2, 1901.

The second method in which the pair of views is taken in the direction of the base line was not considered by me, because it does not lend itself to stereoscopic measurement. It is due to Dr. G. Le Bon (*Les Levers Photographiques et la Photographie en Voyage*, 1889) and will be found described in J. A. Flemer's "Photographic Methods and Instruments" (App. No. 10, *U.S. Coast and Geodetic Survey Report for* 1897).

Forest Department, Cape Town:
1902 *February* 10.

The "Green Flash." By T. W. Backhouse.

I do not know whether there are different phenomena that go by this name, but having seen it several times when the Sun has been setting in the sea I can give a much simpler explanation of

it as seen by me than that given by W. H. Pickering (*Monthly Notices*, vol. lxii. p. 85).

When the Sun is seen through a telescope low down it is bordered at its lower edge, owing to refraction, with the red end of the spectrum, which looks on the whole red or orange-red, while at its upper edge it is bordered with the violet end, which is on the whole green, the extreme end of the spectrum being of course absorbed by the atmosphere. The edges necessarily boil much, but the last portion to set must naturally be a part of the green upper edge, and although I have not observed the green flash with the telescope it is obvious that it is this green edge that is last seen by the naked eye; the boiling of the edge will no doubt account for the appearance like Baily's beads described by one observer with instrumental means.

West Hendon House, Sunderland:
1902 Jan. 16.

Note on the "Green Flash" at Sunset.

By Major E. H. Hills, R.E.

The notes on this subject by Mr. W. H. Pickering (*Monthly Notices*, lxii. p. 85, 1901 November) and Mr. Backhouse above have suggested to me that it may be of some interest if I give a short account of my observations of this phenomenon and of the conclusions I have reached as to its cause. There is, I believe, no doubt that it is of spectral origin, the green being the visually predominant colour in a solar spectrum which attains the requisite degree of purity when the light source, namely the diminishing segment of the Sun's disc, becomes narrow.

If this explanation be the correct one, it will follow that, though the green may be by far the strongest colour, it will not be the last one visible, and a careful scrutiny, under suitable telescopic power, should reveal the more refrangible parts of the expiring spectrum, and thus, as the last portion of the Sun's rim finally disappears below the horizon, we should see the green fade away into blue and violet.

This I have actually observed at least twice, and I have no reason to doubt that it is visible at any time that the atmospheric conditions favour the appearance of a strong green flash.

In observing I used a Zeiss binocular, with a magnifying power of 12 diameters, and was careful to avoid eye fatigue by looking at the Sun only when a very small portion remained above the horizon. Under these circumstances the narrowing segment, which is, of course, of an orange-red colour, is first seen to turn green at its two extremities; the green colour then appears to run inwards until the whole area of the segment appears coloured.

This is the moment when it is visible to the naked eye as the green flash, and after a duration of about a second the green fades away and is momentarily replaced by a blue or blue-violet. The latter is immeasurably more feeble than the green, and its visibility only lasts a small fraction of a second, but it is quite unmistakable, and its appearance seems to prove beyond any question the spectral character of the colours seen.

Further evidence, all tending in the same direction, is found in the fact that the green flash is better seen when the eye has not been previously tired by looking at the red disc of the Sun, whereas if it were a complementary, or fatigue, colour a certain amount of previous gazing is absolutely necessary, and also in the well-authenticated appearance of the same phenomenon at sunrise (see *Nature*, vol. lx. p. 511, 1899 August 31, where Lord Kelvin gives an account of its being seen by him at sunrise in Switzerland), when any retinal fatigue is out of the question. The conditions favourable for its appearance would seem to be :—

1. An atmosphere free from haze and dust; otherwise the light of short wave length will be dispersed and lost, and the green thus made faint or altogether obliterated.
2. A distant horizon, whether land or sea is immaterial ; but, as a dusty atmosphere is practically impossible over the sea, it is on the latter that the phenomenon is generally noticed.

   The distance of the horizon line is an important point. If the air were perfectly free from dust and haze it would be immaterial, within large limits, where the horizon is situated, but practically it is necessary to get as long a column of unilluminated air in front of the observer as possible, and therefore the more distant the horizon the more likely is the flash to make its appearance. I have, for instance, repeatedly tried to see it with a land horizon at about two miles distance, and have, under these circumstances, always failed.
3. A still atmosphere and one homogeneous as to its temperature, or in other words conditions identical with those necessary for good "seeing" in a telescope ; otherwise the irregular dispersion of the air will mask the purity of the colours.

Condition No. 2 leads us up to the fact that the best conceivable circumstances for seeing it would be when the Sun sets behind the horizon at the maximum possible distance—namely, the Moon—provided that the observer is so situated that the Sun is at a very low altitude at the time of eclipse.

Observers of eclipses have naturally always placed themselves so as to get the Sun at as high an altitude as possible, so that the appearance of the green flash at the moment of second or third contact in the case of an annular or total solar eclipse has not yet been recorded.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXII. APRIL 11, 1902. No. 6

Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

George Herbert Bryant, Higher Grade School, Cinderford, Gloucestershire;
Capt. G. P. Lenox-Conyngham, R.E., Survey of India, Mussoorie, India;
S. Alfred Mitchell, A.M., Ph.D., Columbia University, New York City, U.S.A.;
James Rankine, 11 West Saville Road, Edinburgh;
Thomas Thorp, Moss Bank, Whitefield, Manchester; and
William Boultbee Whall, Nautical Surveyor, Board of Trade, Liverpool,

were balloted for and duly elected Fellows of the Society.

The following Candidate was proposed for election as a Fellow of the Society:—

Henry Bridger Adames, 5 West Street, Chichester, Sussex (proposed by W. W. Bryant).

Fifty-seven presents were announced as having been received since the last meeting, including amongst others :—

Circular No. 9 of the Astrophotographic Conference, presented by M. Lœwy ; Catalog der Astronomischen Gesellschaft, Zone +35° bis +40° (Lund), presented by the Astronomische Gesellschaft ; F. C. Penrose, On a method of predicting by graphical construction Occultations and Eclipses, presented by the Author ; Tachkent Observatory Publications No. 3 (W. Stratonoff, Structure de l'Univers), presented by the Observatory ; 8 charts of the photographic chart of the heavens, presented by San Fernando Observatory ; Lantern slides of Meteor, &c., presented by Professor Rees and Mr. Post ; series of astronomical drawings by the late John Brett, presented by Mrs. Brett.

On the Relative Number of Star Images Photographed in Different Parts of a Plate, and on the Performance of Various Object-Glasses in this respect. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. If on a large number of plates taken with the same object-glass, and having a *réseau* impressed upon them, we count the number of star images in each square of the *réseau*, and add together all the results for the same square, it would be pleasant to find that the total number for each square was the same. Such a result would indicate that the object-glass covered the field under survey in an ideally uniform manner ; but in practice we can only expect an approximation to uniformity. Recently we have had occasion to examine the closeness of this approximation in the case of the object-glass used at Oxford for the Astrographic Chart photographs, and the inquiry was extended to an examination of the beautiful charts published by the French Observatories taking part in this work. The results may serve to draw attention to the general question.

2. *The Oxford Object-Glass.*—As a preliminary test of the character of the plate, the number of stars is counted before beginning measurement, and if an insufficient number of stars is found upon it another one is taken under better conditions. The counting is done by a "billiard-marker," and the number of stars in each row of 26 squares (across the plate from left to right) is entered separately. These counts were used to get a general notion of the quantities in question. Five hundred plates were taken simply in the order in which they were counted during the years 1898–1901, and the totals for the rows 0, 1, 12, 13, 24, 25 were formed for each 100. The totals for the outside rows were then expressed as percentages of the mean of rows 12 and 13, the line between these rows dividing the plato into two equal portions of 13 rows each. The results were as follows :

TABLE I.

Counts of Outside Rows of 500 *Oxford Plates expressed as Percentages of the Counts for the Middle Rows.*

No. of Group.	Rows.					
	0.	25.	Mean.	1.	24.	Mean.
I.	67	80	74	78	87	82
II.	74	81	77	83	89	86
III.	83	75	79	90	83	86
IV.	81	63	72	96	81	88
V.	88	99	94	96	99	98
Mean of 500	79	79	79	89	88	88

Thus the extreme outside rows contain 20 per cent. fewer stars than the middle rows, and the next rows within them 12 per cent. less, on the average. But the individual discrepancies are large, and Group V. is specially noticeable as being quite different from the others. No reason could be assigned at the time for the exceptional character of Group V., and a more extended investigation was undertaken. We shall presently see that, as a result of the detailed inquiry, it is possible to assign a reason for the discrepancies (see § 14).

3. For the extended investigation the *measures* of 180 plates (zone $+25°$) were tabulated. In counting the plates, as above, they are passed under review rather rapidly, and sometimes faint stars are passed over; but in measuring a plate each square is carefully examined twice at least, and such omissions should be rare.

4. In Table II. are given the total number of stars in each square of the *réseau* for the 180 plates. The total number of stars is 46,825, which gives an average of 260 per plate. If we exclude the outside rows, so as to include an area $2° \times 2°$, the total is 41,437, and the average 230. Certain features of the object-glass may be seen by inspection. The number of stars falls off rapidly near the edges of the plate, *and also near the centre*, being a maximum about 30′ from the centre. But the accidental irregularities are still very large, even in the mean of 180 plates. To smooth these out the mean of every three adjacent numbers in x was taken, and then the mean of every three adjacent in y; so that the final result, tabulated in Table III., is the mean of a group of nine, of which the element in question forms the centre.

TABLE

Counts of Stars in each Réseau Square on 180 Plates with

$x=$	0	1	2	3	4	5	6	7	8	9	10	11	12
$y=$ 0	46	51	48	49	35	56	59	61	69	77	67	83	61
1	39	51	44	60	54	60	64	63	60	63	89	69	75
2	41	53	42	55	66	66	63	70	74	67	87	83	71
3	56	48	61	58	71	70	69	92	80	77	74	70	78
4	43	40	68	50	59	71	67	68	74	87	85	87	67
5	59	61	67	53	59	70	64	77	80	55	92	72	88
6	60	59	69	68	81	51	66	82	87	72	83	84	70
7	52	72	80	81	84	70	79	70	91	85	78	69	52
8	54	54	73	79	79	80	83	78	72	82	80	75	78
9	59	70	62	75	71	77	77	87	58	74	64	70	60
10	64	56	63	70	77	87	70	69	64	77	69	63	75
11	63	95	79	62	70	56	69	86	84	90	52	79	80
12	50	67	73	60	88	76	64	84	84	73	86	75	66
13	68	68	78	60	69	63	73	85	77	79	62	80	52
14	70	77	72	57	71	95	83	91	91	67	78	70	69
15	52	78	70	71	71	82	69	96	66	77	85	69	79
16	66	67	78	77	56	73	80	87	96	98	80	81	84
17	55	66	79	61	93	82	87	81	94	86	69	78	67
18	53	54	82	87	71	79	81	69	76	93	59	73	103
19	52	76	57	78	76	77	68	60	71	95	89	73	88
20	57	46	61	74	71	64	82	89	72	95	82	76	79
21	40	64	59	64	51	72	66	85	84	76	90	86	82
22	42	57	65	86	70	79	60	84	85	80	83	90	72
23	31	32	44	54	50	65	68	62	56	79	76	56	87
24	30	50	46	41	50	42	59	68	73	67	59	72	91
25	36	43	36	45	51	58	74	45	53	55	44	58	75
Mean	51	60	64	64	67	70	71	77	76	78	75	75	75

TABLE

Means of the Counts shown in Table II. over Squares of 9 Réseau Spaces,

$x=$	1	2	3	4	5	6	7	8	9	10	11
$y=$ 1	46	51	51	56	58	63	65	67	73	76	76
2	48	52	57	62	65	68	70	72	74	75	77
3	50	53	59	63	67	71	73	77	78	80	78
4	56	56	61	62	67	72	75	77	78	78	79

II.

Centres +25°, taken at University Observatory, Oxford.

13	14	15	16	17	18	19	20	21	22	23	24	25	Mean
64	69	57	60	52	61	66	52	42	51	55	39	42	57
70	68	66	75	64	48	75	65	63	63	43	40	39	60
63	56	75	60	61	54	58	65	60	56	65	36	53	62
81	74	79	69	77	59	82	80	67	74	53	38	54	69
90	67	76	72	79	79	85	51	68	77	57	59	35	68
83	89	94	56	74	75	67	72	73	76	59	70	60	71
81	94	75	80	92	74	68	63	82	74	84	61	70	74
73	64	80	66	73	75	62	71	73	70	75	72	65	72
56	88	63	55	84	67	75	71	71	69	61	80	54	72
85	58	63	65	79	82	80	70	72	83	61	79	57	71
69	76	77	86	73	77	74	74	79	72	58	69	59	71
71	84	61	80	85	56	76	82	76	85	72	71	61	74
70	73	85	70	78	84	71	63	65	70	81	62	64	72
67	87	59	84	84	74	82	100	78	75	84	64	56	73
82	67	57	55	67	88	97	77	100	72	67	71	50	75
61	79	77	69	69	79	74	86	87	98	73	75	54	75
75	66	65	66	85	84	88	85	72	73	66	70	51	76
68	72	97	96	85	76	84	79	78	72	81	77	59	78
75	78	87	74	83	93	72	76	100	69	56	68	67	76
78	83	87	89	75	72	74	72	80	59	77	54	53	74
76	83	65	73	87	74	60	66	70	72	63	61	46	71
78	60	85	82	72	73	62	62	45	60	58	65	49	68
74	88	77	77	82	71	65	66	72	54	85	51	56	72
83	72	78	64	69	63	98	62	50	47	45	36	34	60
72	79	62	73	72	70	62	52	62	44	48	40	33	58
68	72	55	74	66	61	62	48	44	36	52	32	38	53
74	75	73	72	76	72	74	70	70	67	65	59	52	69

III.

of which the Central Element is indicated by the arguments given.

12	13	14	15	16	17	18	19	20	21	22	23	24
71	66	65	65	63	60	60	60	61	58	55	50	46
73	71	70	69	69	63	64	65	68	66	60	52	47
77	73	74	70	72	68	70	68	68	66	64	57	50
80	80	82	75	75	71	75	72	72	71	67	63	54

$x=$	1	2	3	4	5	6	7	8	9	10	11
$=y$ 5	58	59	64	62	65	69	74	76	79	80	81
6	64	68	71	69	70	70	77	78	80	77	76
7	64	71	77	75	75	73	79	80	81	79	74
8	64	72	76	77	78	78	77	77	76	75	69
9	62	67	72	77	78	79	73	74	71	73	70
10	68	70	70	72	73	75	74	77	70	71	68
11	68	70	71	72	73	73	75	79	75	74	72
12	71	72	71	67	70	73	79	83	77	75	70
13	69	68	70	71	76	79	81	81	77	74	70
14	70	70	69	71	75	82	81	81	76	74	72
15	70	72	69	73	75	84	84	85	82	78	77
16	68	72	73	74	77	82	84	87	83	80	77
17	67	72	76	75	78	80	84	87	83	79	77
18	64	71	76	78	79	76	76	80	81	79	78
19	60	69	73	75	74	74	74	80	80	80	79
20	58	65	66	70	70	74	75	81	84	85	83
21	55	64	67	70	68	76	78	83	83	84	82
22	48	58	60	66	65	71	72	77	79	79	80
23	45	53	56	60	60	65	68	72	73	74	76
24	39	44	46	51	57	60	62	62	63	63	69

5. Even in the smoothed Table III. there are some irregularities. The northern half of the plate (large values of y) is richer than the southern; but this is almost certainly due, *not* to any peculiarity of the object-glass, but to the distribution of stars in the sky. The general features of this distribution are given in a paper by Mr. Bellamy in *Monthly Notices*, vol. lx., p. 6. A glance at the middle diagram given by Mr. Bellamy (Plate 2, opposite p. 16) will show that for the rich regions 0^h-6^h and 17^h-24^h the number of stars about declination $+25°$ increases as we go north; and for the region 6^h-17^h the distribution is indifferent. A smaller inequality in x is perhaps due to a similar cause. To eliminate this effect, and study the behaviour of the object-glass alone, we may add together squares symmetrically situated on opposite sides of the centre. Taking, for instance, the two diagonals of the plate, there are always four squares at the same distance from the centre, and the mean of the four will be free from errors of distribution in the sky, which increase uniformly in any direction. The centres of these squares will be distant 1, 3, 5, 7, &c., semidiagonals of a *réseau* square from the centre—*i.e.* $3'{\cdot}5$, $10'{\cdot}6$, $17'{\cdot}7$, $24'{\cdot}7$, and so on. Instead of giving the results separately it will be more convenient to give them alongside similar results for other object-glasses, in a comparative

12	13	14	15	16	17	18	19	20	21	22	23	24
80	81	83	78	78	76	77	70	70	71	72	69	62
75	77	81	77	77	74	74	70	70	73	74	71	69
71	73	75	74	74	74	74	69	70	71	73	72	69
68	68	70	67	70	72	75	73	72	72	71	72	67
70	72	71	70	72	74	77	74	74	74	70	70	64
73	73	72	72	74	76	75	75	76	77	73	72	65
72	74	74	77	76	75	74	73	73	74	73	71	66
71	72	73	76	76	77	76	76	77	77	76	74	68
70	70	72	71	71	76	80	82	81	78	77	72	67
70	72	71	70	69	74	79	84	87	86	82	76	66
74	74	70	67	67	73	81	84	85	83	79	74	64
74	72	73	76	79	79	81	82	81	81	78	76	67
78	77	76	78	82	82	83	82	81	78	74	70	66
78	79	81	85	86	82	79	78	80	76	75	68	66
80	82	79	80	80	80	77	73	74	74	72	64	60
79	78	77	78	79	77	72	68	66	65	65	63	58
79	74	76	77	78	77	72	67	63	63	64	63	59
78	77	77	76	76	72	73	69	65	58	58	56	53
77	80	76	74	72	71	73	68	65	56	56	50	47
73	77	71	70	68	68	69	64	60	49	47	42	40

table (Table IV.). A word of explanation may first be given as to the formation of the results for these other object-glasses.

6. *The Paris, Algiers, Toulouse, and San Fernando Object-Glasses.*—Some of the long exposure plates for the Astrographic Chart, taken at these Observatories, have recently been beautifully reproduced by heliogravure, and copies presented to the University Observatory, Oxford, among other observatories. On these copies counts of the number of stars in each square of the diagonals have been made, and the results for the four squares equidistant from the centre added together. It must be remembered that the results are not strictly comparable with those for Oxford plates, the exposures being quite different; so that the loss of stars on the paper charts depends on the increase of stellar density with magnitude near magnitude 14, while for the Oxford plates it is the density near magnitude 11, which may be quite different. It does not appear, however, that the difference is of serious importance for our present purpose. The number of charts counted varies somewhat. From San Fernando only ten charts have been received, and these were all counted. For Paris thirty charts and for Algiers twenty charts seemed to be sufficient to show the features of the distribution clearly; but in the case of Toulouse the results were rather

unexpected, and the counting was extended to forty charts for confirmation. Ultimately, as will presently be explained, the features of the different plates were all satisfactorily accounted for on a hypothesis which is at least a *possible* one. The results for the different Observatories are given in Table IV.

TABLE IV.

Total Counts of Stars in "Réseau" Squares lying along the Plate-Diagonals, for Various Observatories.

Distance of Square from Plate-Centre.	Observatory.				
	Oxford (180 plates).	Paris (30 plates).	Algiers (20 plates).	Toulouse (40 plates).	San Fernando (10 plates).
′					
3·5	255	157	133	228	68
10·6	300	154	145	228	64
17·7	308	173	131	223	66
24·7	303	166	129	248	51
31·8	335	176	148	244	59
38·9	307	214	144	247	61
46·0	276	199	177	238	42
53·0	262	195	152	190	68
60·1	223	242	135	175	46
67·2	272	220	140	153	44
74·2	206	187	128	122	42
81·3	191	155	104	110	34
88·4	162	106	78	81	31
Mean ...	262	180	134	191	52

7. In this table the relative numbers for different Observatories are of no significance at all. The charts were taken just as they came, and some are in richer regions than others. From a glance at the table we see that in no case (except possibly San Fernando) is the maximum number of stars at the centre. For Paris the maximum is even so far as 60′ from the centre, for Algiers about 45′, for Oxford and Toulouse about 30′, for San Fernando doubtful.

8. A good deal of work was done with these numbers, which, though it led up to the final result, need not be reproduced here. The accidental errors were smoothed out by various tentative processes, and the numbers reduced to percentages of (*a*) the density at the centre, or (*b*) the maximum density, and so on. But a simple hypothesis was found to fit all the facts fairly well, and may be given at once.

9. Let us suppose that the field of each object-glass is sensibly curved (fig. 1), so that if F_0 be the best focus at the

centre of the field, that at a distance r from the centre is $y = Ar^2$ nearer the object-glass than F_o. Let the plate cut the curve of best focus at Q, where

$$QM = y_o = Ar_o^2.$$

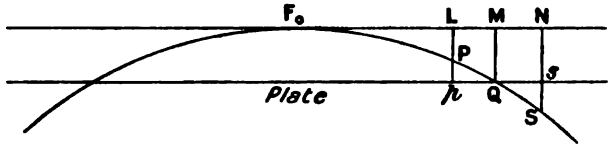


FIG. 1.

Now let us suppose that if we had a curved plate F_oPQ we should get the star density uniform, and that the loss of stars is proportional to the distance of the plate from this surface. Then the density at Q will be a, say, and at P, $a - b \cdot Pp$.

But $$Pp = QM - PL = A(r_o^2 - r^2),$$

$\therefore$ density at P is $$a - Ab(r_o^2 - r^2).$$

When $r > r_o$ we must change the sign of the term in the bracket. In fact the density may be written

$$D = a\{1 \sim c(r^2 - r_o^2)\}$$

10. This hypothesis is only put forward as illustrative; the two main assumptions may be only the roughest approximations; but it seems to fit the facts tolerably well even with a constant value of c for all the five objectives; so that there is something to be said for it. To find the value of c we will take from inspection of Table IV. the following rough values of r_o and the corresponding extreme values of the density.

TABLE V.

Observatory.	r_o.	D when r is 0′.	r_o.	90′.	r_o^2.	$(90^2 - r_o^2)$.	c'_1.	c'_2.
Oxford	32′	260	335	160	1024	7076	220	74
Paris	60	157	242	100	3600	4500	98	131
Algiers	46	133	177	75	2116	5984	117	97
Toulouse ...	32	228	250	75	1024	7076	86	99
San Fernando ...	0?	68	68	31	0	8100	...	68

Since when $r = r_o$ the value of D is a, and when $r = 0$ it is $a(1 - cr_o^2)$, the difference divided by ar_o^2 gives a value of c which we may call c_1. And similarly putting $r = 90'$, and comparing with $r = r_o$, we get a value of c which we may call c_2. In the table these values multiplied by 10^6 are given under the heads c'_1 and c'_2. The mean of the values of c'_1 is 130, and of c'_2 94,

and the latter is determined from rather better divisors. We shall take as a fair assumption $c' = 100$; and thus

$$c = 100 \div 10^6 = 10^{-4}.$$

11. Hence if a plate were placed so that its *centre* was at the best focus the number of stars would fall off at various distances from the centre, as below, taking for simplicity $a = 100$:

Dist. from centre ...	0′	20′	40′	60′	80′
Number of stars ...	100	96	84	64	36

the loss being 2^2, 4^2, 6^2, &c. But if the plate be put within the focus so that the best focus is 20′ from the centre the numbers become

Dist. from centre ...	0	20′	40′	60′	80′
Number of stars ...	96	100	88	68	40

12. Having adopted a value of c it becomes possible to determine a rather more accurate value of r_0 for each Observatory. The process is as follows : Suppose we assume any value of r_0 for Oxford $> 31'{\cdot}8$ and $< 38'{\cdot}9$ (*i.e.* between the 5th and 6th values in the first column of Table IV.), say 35′. Then $acr_0^2 = r_0^2 \times 10^{-4} \times 100 = 12$.

TABLE VI.

Solution for Oxford ($cr_0^2 = 14$ finally).

Dist. from Centre $= r$.	$r^2 \times 10^{-2}$.	O_1.	O_1.	$O_1 - O_1$.	C_2.	$O_2 - C_2$.
3·5	0	88	76	−12	86	−10
10·6	1	89	89	0	87	+ 2
17·7	3	91	91	0	89	+ 2
24·7	6	94	90	− 4	92	− 2
31·8	10	98	99	+ 1	96	+ 3
38·9	15	97	91	− 6	99	− 8
46·0	21	91	82	− 9	93	−11
53·0	28	84	78	− 6	86	− 8
60·1	36	76	66	−10	78	−12
67·2	45	67	81	+14	69	+12
74·2	55	57	61	+ 4	59	+ 2
81·3	66	46	57	+11	48	+ 9
88·4	78	34	48	+14	36	+12
Mean	...	78	78	...	78	...

Forming $r^2 \times 10^{-4} \times 100$ as in the second column of Table VI., and the difference from 12, we subtract this from 100 to get C_1. The mean value of C_1 is 78 ; and the mean value of the column for Oxford in Table IV. is 262. The factor 78/262 or ·298 serves to reduce the Oxford column of Table IV. to the column O_1 of Table VI. ; and $O_1 - C_1$ shows how far we have satisfied the observations. The residuals are negative at first, positive later. Now the value of r_0 is to be adjusted. We have subtracted acr_0^2 from the first five groups in C_1, and added it to the last 8. We can improve the residuals then by increasing acr_0^2. Let us increase it by x. Then so long as x is not greater than 3 the principal effect is to diminish the first five groups by x and increase the last 8 by x. (There is a subsidiary effect arising from the change in the mean value of C_1 ; but this is small, and we may neglect it if the first approximation is good.) Hence changing the sign of the first 5 and adding to the last 8, which gives +27, we may equate this to $13x$ and get $x = +2{\cdot}3$. The effect on the mean value of C_1 is negligible, and thus $O_2 = O_1$.

13. The residuals, however, do not show much improvement, if any, and the determination of r_0 is clearly not a very exact operation. But in this way sufficiently good values of r_0 have been found for the different Observatories as follows :

TABLE VII.

Dist. from Centre.	Paris. $r_0 = 58''{\cdot}3$. $acr_0^2 = 34$. C	O−C	Algiers. $r_0 = 49''{\cdot}0$. $acr_0^2 = 24$. C	O−C	Toulouse. $r_0 = 30''{\cdot}0$. $acr_0^2 = 9$. C	O−C	San Fernando. $r_0 = 34''{\cdot}6$. $acr_0^2 = 12$. C	O−C
′ 3·5	66	+ 1	76	+2	91	+1	88	+14
10·6	67	− 1	77	+8	92	0	89	+ 8
17·7	69	+ 5	79	+2	94	−4	91	+ 9
24·7	72	− 1	82	−6	97	+3	94	−17
31·8	76	0	86	+1	99	0	98	− 9
38·9	81	+11	91	−6	94	+6	97	− 5
46·0	87	− 2	97	+7	88	+8	91	−28
53·0	94	−10	96	−6	81	−4	84	+18
60·1	98	+ 6	88	−8	73	−2	76	− 7
67·2	89	+ 5	79	+3	64	−2	67	− 1
74·2	79	+ 1	69	+6	54	−5	57	+ 6
81·3	68	− 2	58	+3	43	+1	46	+ 5
88·4	56	−11	46	0	31	+2	34	+13

Figures 2, 3, 4, and 5 illustrate these results diagrammatically.

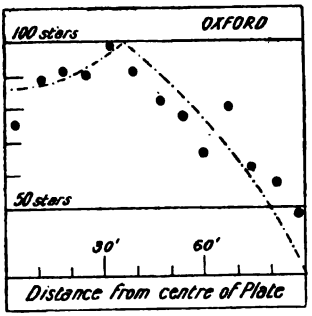


FIG. 2.

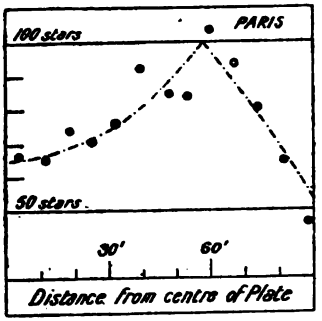


FIG. 3.

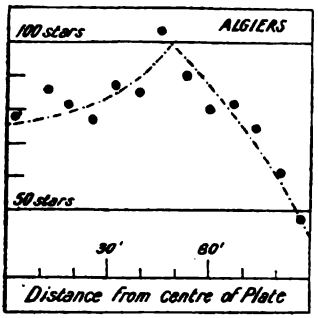


FIG. 4.

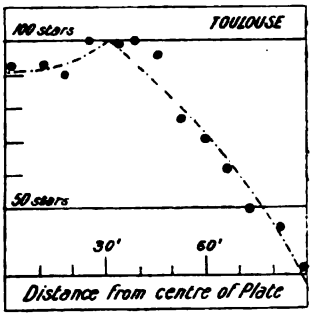


FIG 5.

14. It will be seen from the values of O—C that this rough but simple assumption fits all the facts tolerably well. And there is another observed fact which it will explain equally well. Returning to § 2, it was remarked that the counts of rows on different plates were not consistent. Group V. in Table I. is different from the other groups. Now if the performance of an object-glass be regarded as constant, and if this were the only factor involved, we might find it puzzling to explain such a change. We should have to refer it to errors of counting in some way. But on the present assumption, that apparent differences in performance of the object-glass are mainly due to different positions of the plate within the principal focus, we have an obvious method of explaining the differences in the groups of Table I. It seems probable that the plate-holder has been put back in a slightly different position, and so the outside rows, instead of being deficient compared with the central, as in the earlier groups of Table I., and as shown by the means of rows in Table II., are nearly equal to them. If this is the case our general rule tells us that the new position of the plate must be nearer the object-glass, so that the maximum falls farther from the centre than in Table II.

15. To test this the numbers for other rows of the plates in Group V. were formed; and also for Group I., as a general check. Reduced to percentages they were found to be as follows, rows 0 and 25, 1 and 24, &c., being combined to eliminate the effect of non-uniform star distribution:

TABLE VIII.

	0 and 25	1 and 24	2 and 23	3 and 22	4 and 21	5 and 20	6 and 19	7 and 18	8 and 17	9 and 16	10 and 15	11 and 14	12 and 13
Table II.	80	85	90	100	98	102	105	105	108	107	105	108	103
Group I. of Table I.	81	86	92	100	101	103	109	106	104	104	104	104	106
Group V. of Table I.	91	94	100	102	106	104	102	106	100	102	101	98	97

In Table VIII. the first row refers to the plates in zone $+25°$ analysed in Table II. These were among the earliest plates taken and measured, and the counts are taken from the recorded measures. The second line refers to plates counted with the billiard-marker in 1898. The accordance with the first line is satisfactory, and it may be inferred that the object-glass was not sensibly disturbed up to 1898. But the third line is quite different, the maximum falling much further from the centre.

16. It must be remembered that the maximum is now *for a row* and not for a square, as formerly. Adopting the formula already given the theoretical count for a row, with any given value of r_0, is easily found; and the following results have been obtained, reducing to percentages as before:

TABLE IX.

Value of r_0.

Values of y.	0′	15′	30′	40′	50′	60′
12 or 13	86	87	89	89	85	78
11 „ 14	85	87	89	89	86	79
10 „ 15	84	86	89	89	86	79
9 „ 16	83	85	89	89	87	80
8 „ 17	81	83	88	89	88	82
7 „ 18	78	80	87	89	89	84
6 „ 19	75	77	84	89	89	85
5 „ 20	72	72	81	87	90	86
4 „ 21	68	70	77	84	89	87
3 „ 22	63	65	72	79	88	89
2 „ 23	58	60	67	74	83	89
1 „ 24	53	55	62	69	78	88
0 „ 25	47	49	56	63	72	83
Average	72	74	79	83	85	84

17. The percentages given above are not quite similar to those we have had before, when 100 has been assigned as the mean value of a row. In counts of actual plates we had no means of knowing what the standard was; but in the above table it was supposed that the ideal number for each square (reached only at those squares on the circle of exact focus) was 100, as in Tables VI. and VII.; and we thus see that on the whole fewest stars are lost when r_0 is about 50′. At Paris the plate is rather *too* far within the focus from this point of view; at other Observatories not far enough.

18. But the chief interest of Table IX. lies in its comparison with Table VIII. We see that the first two lines of Table VIII., where the maximum is not very definite, accord very well with $r_0 = 40'$ in Table IX., as we have had independent reason to expect; but the third line in Table VIII. is much better suited by $r_0 = 50'$, or perhaps by a rather larger value than this even. Hence the supposition that the plate-holder was not put back quite into its old position seems to be confirmed.

19. It will be obvious that care must be exercised in making inferences concerning (*a*) the number of stars in a given region, (*b*) the magnitudes of stars in different parts of the plates, especially if the focal adjustments have been changed at any time. It is not proposed to dwell on the details here; rather to draw attention to the matter generally. It may be considered that the quantities discussed in this paper are not serious; but they amount to something like 50 per cent. in number of stars, or, in other words, about a whole magnitude, and I cannot but think that they must be reckoned with in any exhaustive discussion, either photometric or distributive.

20. *The C.P.D. Object-Glass.*—Let us now turn to a different sort of objective. It is remarked in the introduction to the *Cape Photographic Durchmusterung* that the field is practically uniform. As a check on the methods there explained which tend to establish this fact, the number of stars in each minute of R.A. for the zones nearest the equator were counted. The plate centres are at intervals of twenty minutes. and the totals were formed for $0^h\ 0^m$, $0^h\ 20^m$, $0^h\ 40^m$, &c., then for $0^h\ 1^m$, $0^h\ 21^m$, $0^h\ 41^m$, &c., and so on up to $0^h\ 19^m$, $0^h\ 39^m$, $0^h\ 59^m$, &c. Finally, as the effect of change of stellar density in the sky on the run of the numbers was sensible (see § 5 of this paper), the groups for 0^m and 19^m were combined, those for 1^m and 18^m, for 2^m and 17^m, and so on, and the totals reduced to percentages. The results are as follows :—

TABLE X.

Cape Photographic Durchmusterung.

Zone.	0^m and 19^m	1^m and 18^m	2^m and 17^m	3^m and 16^m	4^m and 15^m	5^m and 14^m	6^m and 13^m	7^m and 12^m	8^m and 11^m	9^m and 10^m
$-19°$	101	98	104	96	99	101	102	100	102	97
$-20°$	108	94	93	102	105	97	103	99	105	95
$-21°$	100	111	100	94	96	101	99	104	97	98
$-22°$	100	100	98	102	99	100	104	104	101	90
$-23°$	102	103	104	99	96	104	97	98	97	99

21. These numbers, which are in some ways comparable with numbers occurring in earlier paragraphs of this paper, give a high character for uniformity to the objective used for the C.P.D. The numbers in the last column in Table X. are all less than 100, and those in the first column alone never fall below 100. But beyond this bare fact the columns are distinctly comparable. We have no real discrepancies, approaching 50 per cent., such as have been discussed in the earlier paragraphs of this paper.

22. Have we been right to take the single objective, rather than the photographic doublet, for star-charting? The question has forced itself upon our attention in a number of ways since the decisive step was taken in 1887. It certainly seems, from the discussion in the present paper, that as regards getting a uniform scale of magnitudes over a large area, the doublet is immensely superior to the single objective. Over a field 2° square the latter is obviously defective; over a field 6° square the former gives excellent results. For accurate *positions* of stars the latter *may* be superior (this has yet to be established). But for charting? for the long-exposure plates, which are possibly not intended for the determination of exact positions? To take these long-exposure plates in such small areas as $2° \times 2°$ is immensely laborious; and if they are comparatively defective as well is it even yet too late to reconsider the decision of 1887?

Summary.

As a general summary of this paper the following points may be enumerated:—

A. Counts of star images on plates taken at Oxford (exposure 3^m) and at Paris, Algiers, Toulouse, and San Fernando (exposure 30^m) show that the density of stars photographed in different parts of the plate varies by about 50 per cent.

B. The region of greatest density is not the centre of the plate, but a ring which may be of 35′ (Toulouse, San Fernando, Oxford), 50′ (Algiers), or even 60′ (Paris) radius; in the last

case the density at the centre of the plate is only 0·66 of the maximum density.

C. The differences between these five Observatories may be explained on the hypothesis that the plate is put at different positions within the focus, and without assuming any essential difference in the objectives.

D. The photographic doublet used for the C.P.D. gives a sensibly uniform field over $6° \times 6°$. The question arises, have we got the best instrument for *star-charting*, seeing that it is desirable to have uniformity of magnitude over the field represented?

On Stationary Meteor Radiants. Third Paper.

By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. In *Monthly Notices*, lix. p. 140, it was suggested that the stationary character claimed for certain radiants by Mr. W. F. Denning and other observers might be explained by the cumulative effect of the Earth's attraction on members of the swarm which passed near it at successive returns. It was shown how such members might retain the direction of their velocity relative to the Earth (and therefore their radiant), and yet meet the Earth earlier in its orbit at successive returns. In this way the members of an originally compact swarm would no longer follow nearly the same orbit round the Sun, but would be distributed into a series of orbits, which might differ considerably in shape and size, but would all have two common characteristics.

(*a*) They would all intersect the Earth's orbit, though their crossing points would be distributed round it.

(*b*) When the meteors in any orbit approach their particular crossing point at the same time as the Earth they approach the Earth from the same radiant (*i.e.* with the same direction of relative velocity) as the original swarm.

2. The explanation is by no means free from objections, the most formidable of which is the great length of time required for the action to develop. The very rough quantitative estimate given in the paper was based on the assumption that the velocity or the meteors in their orbit round the Sun is usually parabolic of nearly so; for this seems to be the opinion of meteor observers, though the evidence is not of a high order of accuracy. In a second paper (*Monthly Notices*, lx. p. 450) I endeavoured to show how this might not be a fatal objection.*

* In this paper I also replied to some criticisms of M. Th. Bredikhine, who seemed to have missed the point of the suggestion. M. Bredikhine has since written a second paper (*Bull. Acad. Imp. St.-Pétersb.* Sér. V, tome xiii, No. 2), entirely shifting his ground, but in my opinion making no better case than before.

3. If it should turn out that meteoric velocities are usually sensibly smaller than parabolic it would be more favourable to this explanation; and accordingly my attention was arrested by the results of the photographic determinations of velocity made at the Yale Observatory, which indicate unexpectedly small velocities so far as they go. The account of these experiments which I have seen is a short paper by Dr. Elkin, read at the second meeting of the Astronomical and Astrophysical Society of America (reprinted from *Science*, N.S., xii. pp. 121–129). Five trails were observed, of which one was an *Andromedid*, and was presumably moving in the track of Biela's comet. The observed relative volocities were *not* parabolic, as is seen by the following comparison:

Meteor No.	1	2	3	4	5
Observed *Relative* Velocity (km. per sec.)	49·1	5·0	49·0	16·8	34·7
Theoretical Value	58·3	27·1	60·3	19·6	49·5

No. 4 is the *Andromedid*, and the theoretical velocity is calculated from the orbit of Biela's comet, the others for sensibly parabolic orbits.

4. Dr. Elkin's criticism of these results is:—"The observed velocities lead to orbits of a very improbable character having periods of from 1·25 to 1·80 years, so that it would seem an almost certain conclusion that the atmospheric retardation has amounted to from eight to fifteen km. per sec. for the four meteors."

5. Now, firstly, without laying too much stress on these few observations, I would ask, *Why* are orbits of 1·25 to 1·80 years' period of a "very improbable character"? Merely because of the novelty of the idea? To me it seems, on the other hand, more in harmony with the general habits of the solar system that many of the meteors we encounter should be revolving round the Sun in nearly circular orbits, in which case they would have just such periods.

6. Secondly, if (as Dr. Elkin admits is possible) further evidence shows these smaller velocities to be "somewhere near the cosmic values," then the time required to develop a "stationary radiant" on the lines I have suggested is much shortened. In the first paper (*Monthly Notices*, lix. pp. 148, &c.) it is shown that if

T be the time spent within the Earth's sphere of influence,
e the eccentricity of the hyperbola described relative to the Earth,

and if $f = 1/(e-1)$, then the "time-gain" may be about $fT/23$.

Now, if the relative velocity of approach to the Earth is diminished, both f and T are diminished—f because the hyperbola described relative to the Earth is more curved, and e is

therefore less; and T because the meteor is moving relatively more slowly and stays longer in the sphere of influence.

7. Thus for meteors No. 1 and No. 3 of the above series of five (with relative velocity forty-nine km. per sec.) the time-gain at each return is only about one minute: and it would take at least

$$60 \times 24 \times 365 = 525,600 \text{ encounters}$$

to scatter the swarm completely round the Earth's orbit, *i.e.* certainly many million years. But for meteor No. 5 this time would be reduced approximately in the ratio $(35/49)^2 = 1/2$; and for No. 2 in the ratio $(5/49)^2 = 1/100$.

8. But it is to the suggestion of atmospheric retardation, or to an extension of this suggestion, that I wish in the present paper to draw particular attention. In its ordinary form this notion is quite familiar to meteor observers, who notice sometimes a "slowing up" of the meteors observed, doubtless due to the friction which we know to be large enough to cause their luminosity. Mr. Denning writes in a letter to me:

"In the case of certain long-pathed meteors which I have observed the process of 'slowing-up' has been most marked, and I have recorded a few meteors which almost came to a standstill at the end of their apparent flights."

9. Now, how far away from the Earth does this "slowing-up" extend? That is to say, how far does an atmosphere capable of impeding a meteor's flight, however slightly, extend? We are accustomed to think of the atmosphere as only a few hundred miles thick at most; but this notion is derived from phenomena connected with its action on light (refraction or twilight), and the effect of even the dense air close to the earth is comparatively slight in such cases. At a height where the air is so much rarefied that all twilight effects are insensible, and refraction difficult if not impossible to trace, the density is still so great as to render meteors luminous by friction: and there must be a sensible resistance to their flight far beyond this. We know of no reason why the atmosphere should not extend half-way to the Moon or farther; and considerations of the following kind are in favour of such an extension.

10. In the outer atmosphere the pressure becomes very small, and the "free path" of the gaseous molecules increases. Dr. Johnstone-Stoney has drawn attention* to the possibility of a molecule having sufficient velocity to escape entirely from the Earth's attraction. I do not find myself in agreement with his arguments in the paper quoted, but I am not here concerned with more than this one idea of escape. According to Dr. Stoney's figures, for helium to escape from the Earth's atmosphere a velocity of nine times the mean velocity of a molecule

* *Scientific Trans. of Royal Dublin Soc.* VI. series ii. "Of Atmospheres upon Planets and Satellites."

is requisite. He considers it an established fact that there is sensibly no helium in our atmosphere (recent results show that this is not the case), and concludes that a velocity of nine times the mean is reached sufficiently often to allow of all the helium escaping. From this he argues for other planets, *e.g.* that there is no water on *Mars*. But without following him further, let us consider the idea of a molecule escaping when it happens to have a velocity nine times the mean. Now, however many molecules there may be with this velocity, there must be more with velocities slightly less, say eight times the mean. What happens to these? Clearly in similar cases they will describe orbits which are very large ellipses with the Earth in one focus, just as material particles would. There must, again, be more molecules still with a velocity seven times the mean, and they would describe rather smaller ellipses, and so on. In fact we get a conception of an atmosphere extending a very long way, where the molecules cease to behave like a gas and behave more like satellites. We have scarcely data for forming even a rough guess at the probable resistance this atmosphere might offer at (say) 1000 miles from the Earth's surface to the motion of a small body like a meteor; but there does not seem anything impossible in the supposition that the effect might be sensible.

11. Assuming then that in the neighbourhood of the Earth there may be a resisting medium, however tenuous, what would be the effect on the orbit of a meteor passing near the Earth? By "reducing the Earth to rest," as before, we get the simple case of the meteor, now moving with its velocity *relative to the Earth* only, passing temporarily through a slightly resisting medium. Hence

(1) The velocity (*i.e.* relative velocity) will be slightly diminished in magnitude.

(2) It will not be altered in direction. Further,

(3) On leaving the resisting medium the meteor will, owing to the diminution of velocity, be slightly *behind* the place it would have otherwise occupied; there is a *delay*, of the same kind as the *acceleration* due to the Earth's attraction.

12. In fact these effects are almost precisely those which have been already shown (in the case of the Earth's attraction) to produce a "stationary radiant." No. 2, the constancy of the velocity in *direction* means that the radiant is unaltered; and No. 3, the slight delay, means that the meteor is encountered by the Earth slightly *later* on the next return; so that by cumulative action at successive returns some meteors might be gradually spread along the Earth's orbit, with a constant radiant.

13. There are, however, two important new features in this action of a resisting medium as compared with that of the Earth's attraction. First, the relative velocity of the meteor is diminished each time it passes through the medium, and hence will diminish continually. This is a distinct gain as compared with our former explanation of stationary radiants, for in that the relative velocity

was left unaltered in magnitude, and this is not in accordance with observed facts (see *Monthly Notices*, vol. lix. p. 146). But, secondly, when we come to calculate quantitatively the possible *amount* of spreading of the shower, due to the delay, we find it strictly limited in amount, and such as will not explain any long duration of a stationary radiant.

14. Let v be the velocity with which the meteor enters the resisting medium at any return, and $v+dv$ that with which it leaves, dv being of course negative. Let v_0 be the original velocity and T the original time spent in the medium, so that the space traversed is v_0T. The time of traversing this space with velocity v is $v_0\mathrm{T}/v$; and if the velocity v change uniformly to $v+dv$ during the traverse, the time spent will be $v_0\mathrm{T}/(v+\frac{1}{2}dv)$, so that the delay at this particular return is $-\frac{1}{2}v_0\mathrm{T}\dfrac{dv}{v^2}$. The total delay occasioned by a change from the original velocity v_0 to v_1 is thus

$$-\tfrac{1}{2}v_0\mathrm{T}\int_{v_0}^{v_1}\cdot\frac{dv}{v^2}=\tfrac{1}{2}\cdot\frac{v_0-v_1}{v_1}\cdot\mathrm{T}.$$

15. Now the factor $(v_0-v_1)/v_1$ may theoretically be made as large as we please by diminishing v_1 sufficiently; but in practice it does not seem likely that it would be large. Taking, for example, the velocities observed at Yale as in §3, the largest value of $(v_0-v_1)/v_1$ is that for meteor 2, where $v_0=27{\cdot}1$ and $v_1=5{\cdot}0$; so that $(v_0-v_1)/v_1=4{\cdot}4$. If, further, we suppose the meteor to be originally within the resisting medium for 270,000 kilometres, or 10,000 seconds, which seems an extreme supposition, we get T = 10,000 sec. = 3 hours about, so that the total "delay" is less than seven hours. For the formation of a "long-enduring" radiant this quantity (which probably represents an extreme limit in every way) is negligible.

16. Hence the effect of the resistance of the Earth's atmosphere, though it is of the same kind as that of the Earth's attraction in many respects, is not indefinitely cumulative, and is in fact limited to a total amount which is negligible. The resistance of the atmosphere cannot be the *sole* cause of a stationary radiant.

17. But it may be a *contributing* cause. Those meteors which are subjected to the possible retardation of the atmosphere by hypothesis pass near the Earth and are subject to its attraction, as before considered, and *vice versa*. In fact we must consider the effect of *both causes conjointly*. Now the latter (the Earth's attraction) alone can be responsible for any great spreading action; but in another feature the effect of the former (atmospheric resistance) is the more important, viz. in the change of relative velocity.

18. It has been shown in the earlier papers that the Earth's attraction leaves the relative velocity of the meteors unchanged. But in § 11 it has been remarked that the atmospheric retardation

continually diminishes this relative velocity. Is this the source of the difference in velocities of meteors from the same stationary radiant observed by Mr. Denning? We must first remark which meteors will be most affected: obviously those which have been subjected to the atmospheric retardation, and therefore also to the Earth's attraction, most often and most severely. From the operation of the second cause these will be meteors encountered *earliest* in the Earth's journey through the series of showers—*i.e.* the Earth should meet slow meteors first and quick ones later. Now Mr. Denning's observed rule is quite different, at any rate in form. He says: "The meteors from showers which are moving in an opposite direction to the Earth are generally much swifter than meteors travelling with the Earth." The two rules could not agree completely; but the observed facts might by chance satisfy both. To test this I wrote to Mr. Denning for some examples, asking him whether slow meteors came early in the encounter with the radiant and quick ones late. He promptly replied (1902 March 15) by some examples which do *not* fall in with the suggested rule, and the suggested explanation falls through. One or two of the examples may be given:—

Radiant 23°+44°. *G.C. xxi. γ Andromedids.*—Meteors very swift with streaks in July and August; in September rather swift; in October slow, and in November very slow.

Radiant 30°+36°. *G.C. xxv. β Triangulids.*—Meteors very swift with streak in July and August; in September rather swift; in October swift; in November and December slow and trained.

Radiant 63°+21°. *G.C. liii. ε Taurids.*—Motion very rapid in August and September; in October rapid; in November slow. The same may be said of a bordering shower of *Taurids* from a radiant of about 57° +9°.

Radiant 61°+49°. *G.C. lvi. μ Perseids.*—Very swift in July, August, September, and November.

Radiant 270°+24°. *G.C. ccv. Herculids* (97).—Meteors very swift with streak in April; slow in July and August.

Radiant 296°+1°. *G.C. ccxxx. η Aquilids.*—Meteors very swift with streak in April and May; slow and very slow in July and August.

19. It thus seems clear that no improvement in the theory already advanced is afforded by considerations of atmospheric retardation, except in the sense indicated in §§ 6 and 7—*i.e.* that the development of a long-enduring radiant may not take so long. But, as the question of atmospheric retardation arises naturally in connection with this question of the Earth's attraction, this examination of the point may as well be put on record, although the general result is negative.

General Conclusion.

In connection with a theory of stationary radiants of meteors as due to the attraction of the Earth, advanced in former papers

(*Monthly Notices*, lix. p. 140 and lx. p. 450), the question of possible atmospheric retardation of meteors passing near the Earth has been examined. This retardation is suggested by the small velocities observed by Elkin; and if such small velocities are found to be the rule the time required to establish a long-enduring radiant on the lines already suggested is curtailed. The atmospheric retardation may also itself exercise a spreading action on the radiant of the same kind as that exercised by the Earth's attraction, but so small in amount as to be negligible, and an accompanying effect on the relative velocity is apparently not in accordance with observed facts.

Anomalous Occultation of Stars by the Moon.

By G. W. Hough.

(*Communicated by the Secretaries.*)

In the *Monthly Notices* for 1901 April Mr. R. T. A. Innes has published an article on anomalous occultations; and subsequently a number of communications, on the same topic, by Mr. Innes and others have appeared in the Observatory.

The subject is one of considerable interest in its bearing on the discovery of double stars, due to the abnormal phenomena which may be observed.

During the past four years I have observed nearly 300 occultations with the 18½-inch refractor of the Dearborn Observatory, using a power of 190.

With this optical power any abnormal phenomena would be well seen, except for faint stars near the time of full Moon. I have noted four classes of phenomena:—

1. Instantaneous disappearance.
2. Slow disappearance.
3. Sudden change in the brightness of the star.
4. Projection of the star on the Earth-lit disc of the Moon.

For the first case, or normal disappearance, the star seems to dive under the disc of the Moon.

For the second case the motion of the star is smooth, requiring an appreciable time to disappear, viz. $0^s{\cdot}2$.

For a phenomenon of this kind I agree with Mr. Innes that the star may be a very close double, probably beyond the reach of any telescope.

For the third case, in which there is a sudden change of brightness, the star is obviously double, and in most cases will be within the reach of existing telescopes.

A number of examples, however, have been cited, of known double stars, in which the distance of the components was 1″ or more, which were seen by the observer to "disappear gradually," whereas there should have been a sudden change in brightness.

The failure to see the real phenomenon was due to insufficient optical power, as will readily appear from the observations which follow. A small telescope and low power will not exhibit the phenomenon in the same manner as an instrument of greater power.

Double stars like *Antares*, or, in fact, all double stars, in which the components are not very unequal, and the distance not less than 2″, may be seen and recorded separately by the use of optical power equal to that I have employed.

I append such examples from my list of observations :—

1898 February 23. Σ67 8·2—9·1 mag. $p = 7°$ $s = 1''·86$.

"Companion disappeared 1^s later."

1898 June 30.

a Scorpii 1—8. mag. $p = 271·9$ $s = 3''·13$.

"Companion disappeared $4^s·8$ earlier."

1900 January 7. Σ 67 $p = 7°$ $s = 1''·86$.

"Companion disappeared $6^s·94$ later."

In (*A.J.*) 488 I have published a list of 193 occultations. Two interesting cases of abnormal phenomena were noted.

1897 March 3. 7·5 magnitude star. "Suddenly diminished to one-half brightness before disappearance." This star was subsequently identified as Ho 247. 87·22 $p = 101·3$ $s = 0''·36$ 7·5—8 magnitude. A very close double.

(*A.J.*) 474. 1899 October 21. *τ Tauri* 4·4 magnitude. "Reappeared first as a 9th-magnitude star, and after an interval of rather more than one second it flashed out in full brightness."

This star is without doubt a double, but, owing to the closeness and inequality of the components, it is probably now beyond the reach of any telescope.

From the apparent path of the star I determined the position of the companion $p = n.p.$ $s = 0''·15$ to $0''·4$. It is probable that no abnormal phenomena would be noticed, except for an emersion occurring between 300° and 360°, position angle.

In an unpublished list of ninety-three occultations are the following :—

1901 April 27. B.D. $+4°·2333$ 7·5 magnitude. "About one-half the light was suddenly shut off before final disappearance." The star was subsequently identified as

OΣ 218. 98·67 $p = 70·6$ $s = 1''·15$ 7·3—9·2 mag. Hω 5″.

1901 February 25. B.D. $+20''·807$ 9· mag.

"apparently disappeared, then seen again ; the final disappearance being $3^s·8$ later."

This star was found to be

Ho 332. $p = 126°$ $s = 1''·03$ 9—9 mag.

The computed interval for the occultation of the two components was $2^s \cdot 5$.

It would appear from theory that any double star, of which the components are approximately equal, and the distance not less than $0''\cdot 1$, would exhibit abnormal phenomena when occulted, provided sufficient optical power was used for its observation.

1901 October 17. B.D. $-20° \cdot 4810$ 8·7 mag.;
position angle of contact 106°. "Star appeared to be on the limb two or three seconds before disappearance. Moon's age, five days."

I have on a number of occasions seen 8th and 9th magnitude stars partially buried in the limb before disappearance.

The increased size of the Moon due to irradiation may appear to retard the actual occultation of all stars when they are in contact with the luminous disc. But when a star passes on the disc, beyond the visible boundary of the limb before it disappears, some other explanation seems necessary.

The limb of the Moon is not a smooth surface, but consists of elevations and depressions. When illuminated by Earth light the limb, however, appears comparatively smooth, since the eye cannot distinguish the minute irregularities. The apparent motion of a star occulted by the Moon varies approximately between $0''\cdot 3$ and $0''\cdot 6$ for one second of time. It might therefore happen, taking into account the known elevations and depressions of the lunar surface, that a star could enter an opening in the limb and remain visible a number of seconds before disappearance.

That there are considerable elevations and depressions in the Moon's limb is a well established fact.

During the total eclipse of the Sun in 1869 I recorded on a chronograph, $9^s \cdot 3$ before the true contact of the limbs, a lunar mountain, distant eight or ten degrees north of the computed contact point.*

From what has already been said it seems reasonable to infer that, under certain conditions, a star may actually advance one second of arc, or more, beyond the visible boundary of the limb before it is occulted.

According to this view the most favourable condition for the projection of a star on the disc would be when the apparent path was radial to the limb. For a very oblique approach the phenomenon should be less pronounced.

An analysis of all recorded instances of stars projected on the luminous disc of the Moon might lead to a better understanding of the subject, but it must be kept in mind that small telescopes do not show the phenomena in the same manner as large ones.

Dearborn Observatory, Evanston: 1902 *February* 10.

* *Annals of the Dudley Observatory*, vol. ii.

Saturn Visible through the Cassini Division.

By C. T. Whitmell, M.A.

In August 1899, when engaged in studying the planet *Saturn* as a view-point, I found that there would be for *Saturn* a solar transit of the Earth on 1902 July 17. Such transits occur when (the Earth being in inferior conjunction with the Sun) *Saturn* is within about 5° 25′ of heliocentric longitude of his nodes—that is, when the heliocentric latitude, N. or S., does not exceed some 14′.

On 1902 May 24, at 5^h G.M.T., *Saturn* is at his descending node in longitude 292° 50′ 8″, and is in opposition to the Sun on 1902 July 17, at 13^h G.M.T., in longitude 294° 28′ 57″ and south latitude 0° 4′ 17″·7. The conditions for a solar transit of the Earth will therefore be satisfied on July 17.

To *Saturn* the disc of the Sun will be 192″ in diameter, that of the Earth only 2″. The chord of transit, 183″ long, lies 29″ N. of the Sun's centre, and the duration of transit of the Earth's centre for *Saturn's* centre is about $11^h\ 42^m$.

It appears also that an observer, placed in Saturnian latitude about 27° south and in a suitable longitude, will be able to view, through the Cassini division, a portion of the transit.

If we assume, with Professor Barnard, the division to be 2,270 miles broad, and the thickness of the ring-system to be 50 miles, then this division will have, at right angles to the sight-line, a projected meridional breadth of about 820 miles, corresponding to about one degree of arc for the observer on *Saturn*.

At the given date, July 17, the Saturnicentric declination of the Sun is diminishing, that of the Earth increasing, and about 7^h G.M.T., or only 6^h before opposition, the Sun and the Earth are equally elevated above the ring-plane, their declination being about 22° 26′ 17″ N.

We have next to consider the matter from a terrestrial standpoint. If an observer on *Saturn* is able, through the Cassini division, to see a solar transit of the Earth, it follows that a line drawn from the Sun to the Earth can pass through this rift in the rings to the surface of *Saturn*. Thus a terrestrial observer, suitably placed, will be able to view through the rift a portion of the planet's surface lit up by sunlight, which passes through the rift, and is reflected back by the planet through the rift to the observer.

The practical effect will be that, of the arc of the Cassini division crossing the planet, a small portion will appear bright instead of dark, and may almost disappear, but probably will not quite do so, because the albedo of *Saturn* is less than that of the adjacent portions of rings A and B, which bound the fissure. Hitherto there is, I believe, no record of such a phenomenon having been observed.

Taking the actual breadth of the division as 2270 miles, and the thickness of the rings as 50 miles, I estimate, as before, the effective width of the rift (at right angles to the line of sight, and measured in the direction of a Saturnian meridian) as 820 miles, when seen from an elevation of 22° 26′ 17″ above the ring-plane.

At the Earth's distance this width corresponds to an angular breadth of only 0″·20, so that the observation will be one of peculiar delicacy and difficulty.

As already pointed out, only when *Saturn* at opposition is in the neighbourhood of a node is it possible for there to be a solar transit of the Earth, and only then can the Sun and the Earth be in line with the planet through the Cassini division It happens also that when *Saturn* is near a node the elevation of both Earth and Sun is considerable, so that the gap is well open along the line of sight.

But, if at an opposition there is an appreciable difference between the Saturnicentric declinations of Earth and Sun, the area of the planet, on the line of sight through the gap, will be shadowed by the A ring if the Sun is lower, and by the B ring if the Sun is higher, than the Earth, so that the Cassini division will appear as dark where it crosses the planet, as it does where it crosses the sky.

I hope that the conditions pointed out, which rarely occur, may lead such astronomers as are favourably situated to make what may prove to be a unique observation. As the exact limits are not easily determinable, it seems desirable that the planet should be watched for a few days, about 1902 July 17, from Observatories distributed over a wide range.

Leeds: 1902 *March* 29.

On the Supposed Variability of κ Persei and 36 Persei, and a Comparison of the Photographic and Visual Magnitudes of these Stars. By W. H. Robinson.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

Two of the brighter stars used for comparison of magnitude with Nova *Persei*, viz. κ *Persei* and 36 *Persei*, have been announced as New Variables in the *Astronomische Nachrichten*,* where the Nos. assigned to them are respectively 74, 1901 and 75, 1901.

As the variability of these stars seems to have been assumed on inadequate grounds, it occurred to the writer that the data

* *Ast. Nach.*, No. 3720.

afforded by his photographs * of the region of Nova *Persei*, taken in 1901 February, March, and April, would furnish some useful evidence on the subject.

The measured photographic magnitudes of the two stars have accordingly been tabulated and plotted on square-ruled paper. In addition to these, by Dr. Rambaut's permission, some visual observations of magnitude taken at the Radcliffe Observatory are included for comparison. The visual magnitudes obtained at Poppelsdorf-Bonn by Dr. P. Guthnick, and at Bonn by Professor F. Deichmüller, are also discussed.

It will be convenient to examine the data for κ *Persei* and 36 *Persei* separately.

Dr. Guthnick's series of magnitudes of κ *Persei* from which he derives variability are the following :

TABLE I.

Poppelsdorf-Bonn Visual Magnitudes of κ Persei.

G.M.T.		Mag.	Diff. from Mean.	Compar. Stars.
1901	h			
Mar. 21	7½	3·77	+0·27	ν, ρ, 38, ξ
	9	3·45	+0·59	ν
24	8	3·98	+0·06	ν
30	9	4·18	−0·14	ν
	9½	4·13	−0·09	ν
Apr. 1	10½	4·12	−0·08	ν, *l*
4	9½	4·23	−0·19	ν
	10½	4·09	−0·05	ν, σ
	11	4·13	−0·09	ν
9	8	4·12	−0·08	ν, ξ
18	8	4·22	−0·18	ν, *l*
	8½	4·22	−0·18	ν, *l*
22	8½	4·20	−0·16	ν, Arg. +43°, 818
23	9	4·22	−0·18	ν, *l*
	9½	4·27	−0·23	ν, *l*
May 18	9½	4·0(:)	+0·04	*l*
22	10	3·78	+0·26	ν
24	9⅓	3·71	+0·33	ν
	9½	3·81	+0·23	ν

Remarking on these results, Dr. Guthnick says :

" Die Schwankungen der Helligkeit betrugen rund $0^m·6$, die Periode scheint mindestens gleich zwei Monaten zu sein."

It should be pointed out that, of the above magnitudes, those

* Vide *Monthly Notices R.A.S.*, vol. lxii., No. 3.

which occur in March and April are entitled to much greater weight than those in May, since in the latter month the constellation of *Perseus* is very low, and corrections required for atmospheric absorption are in consequence more or less doubtful.

The results point to a maximum brightness on or near March 21, and a minimum about April 23. It happens, fortunately, that on both of these crucial dates three observers at the Radcliffe Observatory secured estimations of magnitude of the star. A reference to the means in Table II., which follows, will show that the Radcliffe observations, instead of confirming a *fall* of $0^m{\cdot}6$ between the two dates, indicate either a *rise* of $0^m{\cdot}1$, or more probably (when a small observational error is allowed for) a *constancy* of brightness.

TABLE II.

Radcliffe Visual Magnitudes of κ Persei.

G.M.T.	Mean Mag.	Number of Observers.	Diff. from Mean.
1901 Mar. 9	3·85	3	+0·16
16	4·00	2	+0·01
20	4·13	1	−0·12
21	4·08	3	−0·07
23	3·95	2	+0·06
24	4·10	1	−0·09
26	3·93	2	+0·08
27	3·96	2	+0·05
28	4·03	3	−0·02
30	4·08	3	−0·07
31	4·09	1	−0·08
Apr. 1	4·08	1	−0·07
4	4·11	1	−0·10
5	4·07	1	−0·06
8	4·00	3	+0·01
9	4·07	2	−0·06
10	3·94	1	+0·07
12	3·98	2	+0·03
13	3·96	2	+0·05
17	4·19	1	−0·18
23	3·96	3	+0·05
24	3·86	1	+0·15
May 13	3·92	1	+0·09
22*	3·87	1	+0·14

* May 22 "Very low, near meridian, *sub polo*.

The results of the Radcliffe visual observations clearly suggest the necessity for further evidence before accepting Dr. Guthnick's conclusions, and such evidence is provided in the photographs.

In the next table (III.) the photographic magnitudes of the star are exhibited (column 6). The scaled values of brightness, from three independent series of measurements, determined in the manner described in the *Monthly Notices*, vol. lxii., No. 3, are given in columns 2, 3, 4. The next two columns contain the mean scaled values and their equivalents in magnitudes. The last column shows the differences from the mean, 4·70.

The stars used for comparison were *r*, *l*, and 30 *Persei*.

TABLE III.

Photographic Magnitudes of κ Persei.

G.M.T. 1901	h	Photographic Scaled Densities. 1st Series.	2nd Series.	3rd Series.	Means.	Photogr. Magn.	Diff. from Mean.
Feb. 25	8	58·5	59·5	59·5	59·2	4·69	+0·01
26	10	59·5	60	59	59·5	4·72	−0·02
28	9	59·5	59·5	57	58·7	4·66	+0·04
Mar. 5	7	56·5	57·5	58·5	57·5	4·58	+0·12
9	9	59	59·5	59·5	59·3	4·70	0·00
	9½	59	59·5	61	59·8	4·74	−0·04
16	8	59·5	59·5	60	59·7	4·73	−0·03
	9	57	59·5	60·5	59·0	4·68	+0·02
21	9½	60·5	60·5	60	60·3	4·77	−0·07
	11	58·5	57·5	60·5	58·8	4·67	+0·03
22	8	60·5	59·5	60·5	60·2	4·76	−0·06
25	8	59·5	58	57	58·2	4·62	+0·08
	11	59	58·5	56·5	58·0	4·61	+0·09
27	11	60	60·5	58	59·5	4·71	−0·01
28	9	60	59·5	59	59·5	4·71	−0·01
30	9½	59	59·5	55·5	58·0	4·61	+0·09
	10½	60	60	57·5	59·2	4·69	+0·01
Apr. 10	9	60	61	61·5	60·8	4·81	−0·11
13	9	58·5	60	59	59·2	4·69	+0·01
15	11	59	57·5	60·5	59·0	4·68	+0·02
17	9	60·5	61	61	60·8	4·81	−0·11
19	9½	60	60·5	57·5	59·3	4·70	0·00
20	9	58·5	60·5	60	59·8	4·73	−0·03

The mean photographic magnitude of *κ Persei* is 4·70, or 0·69 fainter than the mean visual magnitude, 4·01, the difference being probably attributable to the orange colour of the star.

The residuals in the last column of Table III. are too small to admit of the deduction of any law of sensible variation of the star's brightness during the period embraced in the table, viz. February 25 to April 20.

Fig. 1, given at the end of this paper, exhibits graphically the data given in Tables I., II., and III. The correction, $-0^{m}\cdot69$, referred to in the last paragraph but one, has been applied to the magnitudes from Table III., to make the photographic and visual magnitudes directly comparable.

It will be seen that the photographic and Radcliffe visual magnitudes of κ *Persei* are best represented by a constant, and not (as in the case of the observations at Poppelsdorf-Bonn) by a variable.

The magnitudes of 36 *Persei* will be next considered.

The observations at Bonn, from which Professor Deichmüller deduces variability, are given in the second column of Table IV., whilst Dr. Guthnick's and the Radcliffe magnitudes appear in the next two columns.

TABLE IV.

Visual Magnitudes of 36 *Persei.*

G.M.T. 1901.	h	Observed Magnitudes. Deichmüller.	Guthnick.	Radcliffe.	Differences from Mean. D.	G.	R.
Mar. 28	9	5·55	5·67	...	−0·25	−0·16	...
29	8	5·60	...	...	−0·30	...	...
Apr. 7	9	5·65	5·73	...	−0·35	−0·22	...
10	9	...	...	5·30	...	...	+0·09
14	9	...	...	5·35	...	...	+0·04
19	10	5·48	...	...	−0·18	...	...
20	9	...	5·58	5·40	...	−0·07	−0·01
21	8½	...	$5\cdot46_2$	5·30	...	+0·05	+0·09
22	9	5·40	$5\cdot42_4$	...	−0·10	+0·09	...
23	9½	5·36	...	...	−0·06	...	...
25	9	...	...	5·41	...	...	−0·02
May 12	10	...	...	5·55	...	...	−0·16
21	13½	4·98	...	...	+0·32	...	...
22	10	...	$5\cdot18_3$	...	...	+0·33	...
	14	$5\cdot06_3$	...	...	+0·24	...	...
23	9½	4·92	...	...	+0 38	...	...
24	13	5·01	...	...	+0·29	...	...
Means	...	5·30	5·51	5·39			

Remarking on his observations, Professor Deichmüller says: "Bei meinen Grössenbestimmungen der Nova *Persei* nach der Methode der Stufenschätzungen habe ich öfter auch 36 *Fl. Persei*

als Vergleichstern benutzt und dabei eine Veränderlichkeit desselben von ½ Grössenclasse wahrgenommen. Der Stern scheint jetzt im Maximum zu sein ; die Beobachtungen könnten durch eine etwa zwei-monatliche Periode dargestellt werden." *.

Dr. Guthnick, in the same number of the *Astronomische Nachrichten*, publishes his observations as confirming Professor Deichmüller's.

Both of these observers record an *increase* of $0^m.5$ in the star's light between April and May ; but the Radcliffe visual magnitudes tend to show a *decrease* by May 12, when the observations were secured under very favourable atmospheric conditions, the sky being noted as "exceptionally clear." The comparison stars used on the latter date were *l Persei*, 30 *Persei*, *Arg. Z.* +43° 818, and *Arg. Z.* +44° 648.

The photographic magnitudes in Table V. are the results of three independent series of measurements, and are therefore reliable.

TABLE V.

Photographic Magnitudes of 36 Persei.

G.M.T. 1901.	h	Photographic Scaled Densities. 1st Series.	2nd Series.	3rd Series.	Means.	Photogr. Magn.	Diff. from Mean.
Feb. 25	8	70·5	70·5	71	70·7	5·50	+0·03
26	10	72·5	72	72	72·2	5·60	−0·07
28	7	71	72	71	71·3	5·54	−0·01
	9	69·5	70·5	71	70·3	5·47	+0·06
Mar. 5	7	71·5	70·5	71	71·0	5·52	+0·01
9	9	70·5	70	71·5	70·7	5·50	+0·03
	9½	72	68	68	69·3	5·40	+0·13
16	8	72·5	74	71·5	72·7	5·64	−0·11
	9	71	74	71·5	72·2	5·60	−0·07
21	9½	70·5	73	72	71·8	5·58	−0·05
	11	72	74	71	72·3	5·61	−0·08
25	8	71	71·5	71·5	71·3	5·54	−0·01
	11	69·5	71	71	70·5	5·48	+0·05
26	9	71	70	71·5	70·8	5·51	+0·02
27	11	70·5	71·5	72	71·3	5·54	−0·01
28	9	70·5	71	70	70·5	5·49	+0·04
30	9½	70	72	70	70·7	5·50	+0·03
	10½	70·5	70	71·5	70·7	5·50	+0·03
Apr. 10	9	71·5	71	72	71·5	5·56	−0·03
13	9	69·5	71	71	70·5	5·48	+0·05
15	11	71·5	70	70·5	70·7	5·50	+0·03
20	9	70·5	71	70·5	70·7	5·50	+0·03

* *Ast. Nach.*, 3720.

In forming the means given in col. 5 of the preceding table, perhaps the 3rd series (col. 4) should have received the greatest weight; for the results in this series depend upon a special set of estimations, selecting three comparison stars of suitable brightness, and situated most favourably for the determination, by the differential method, of the magnitude of the star in question. The estimations in the 3rd series will be found to be in closer accordance than those of the other two series, which are probably affected, though only in a slight degree, by differences of atmospheric absorption.

The comparison stars used in Series 1 and 2 were generally six in number, viz. *l Persei*, 30 *Persei*, *Arg.* $Z.+43°$ 818, *Arg.* $Z.+45°$ 811, *Arg.* $Z.+44°$ 734, and *Arg.* $Z.+42°$ 795; whilst those of Series 3 were *Arg.* $Z.+45°$ 811, *Arg.* $Z.+46°$ 760, and *Arg.* $Z.+45°$ 804.

The photographic and visual magnitudes of 36 *Persei* (Tables V. and IV.) are exhibited graphically in fig. 2.

The magnitudes resulting from the photographic method are well represented in the diagram by an almost horizontal straight line, whilst the line drawn through the Radcliffe visual estimations is slightly curved, but in the direction opposite to that of the line drawn through the observations at Bonn and Poppelsdorf-Bonn. A curious feature in the latter is the fact that a rise of magnitude of both κ and 36 *Persei* occurs in May nearly simultaneously; but (as before pointed out) the stars in the constellation of *Perseus*, during the observing hours of the month of May, were low, and especially so in the case of the observations at Poppelsdorf-Bonn. Corrections for atmospheric absorption appear to have been applied where necessary, but such corrections to observations at small altitudes are necessarily somewhat arbitrary and uncertain.

The evidence afforded by the photographs and by the Radcliffe visual observations seems to give an emphatic negative to the hypothesis of the variability of these two stars.

Radcliffe Observatory, Oxford:
1902 *March* 9.

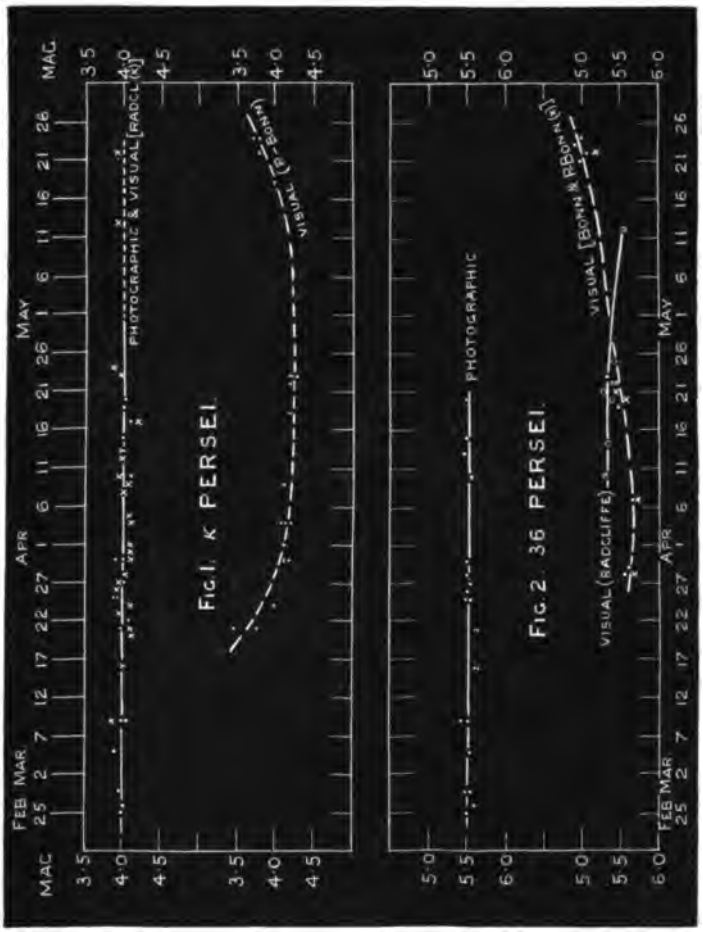
Addendum.

Further evidence—received to-day*—strongly confirms the conclusions arrived at in the present paper. The observers at Potsdam remark: "Wir haben 36 *Persei* in der Zeit von 1900 Oct. 9. bis 1902 Febr. 15. 15 mal, κ *Persei* von 1898 März 13. bis 1902 Feb. 15. 22 mal und B.D.$+43°$ 730 von 1899 Sept. 20. bis 1902 Febr. 15. 43 mal beobachtet und bei allen drei Sternen eine

* *Ast Nach.* 3779.

so bemerkenswerthe Constanz der Helligkeit gefunden, dass ein sehr viel zwingenderes Material, als bisher veröffentlicht ist, erforderlich wäre, um uns von der Veränderlichkeit der Sterne zu überzeugen."

Radcliffe Observatory, Oxford:
1902 March 25.



On the Probable Motion of some of the Small Stars in the "Dumb-bell" Nebula (M 27, N.G.C. 6853). By E. E. Barnard.

In *Monthly Notices* for March 1894 (vol. liv. No. 5) Messrs. A. Rambaut and W. E. Wilson give a list of the photographic places of some of the stars in M 27, compared with the places determined by Otto Struve some forty-two years previously. These show large discordances, in many cases amounting to as much as 5″ or 6″ in the different coordinates. These discordances the authors of the above paper attribute to proper motion in these stars. Such considerable motion in so many small stars seems improbable, and if real would be of the highest interest.

In 1894 I measured several of these stars with the 36-inch at Mount Hamilton to verify the photographic results. These showed that the discordances were real. A paper on the subject was printed in *Astronomy and Astrophysics* for June 1894.

Several years ago I remeasured three of these stars and measured an additional one. I have just come across these measures and have thought it well to send them to *Monthly Notices*, where they may be properly recorded. As I think there is good reason to believe the supposed proper motions are not real, I have not thought it necessary to measure all the discordant stars mentioned by Dr Rambaut.

As usual the measures have been made in position angle and distance (double distances being measured). For comparison with the previous measures these have been reduced to $\Delta\alpha$ and $\Delta\delta$. In the reduction to $\Delta\alpha$ the measures have not been multiplied by secant of δ.

Following are the measures with the 36-inch :—

			$\Delta\alpha\,(x-a)$	$\Delta\delta\,(x-a)$
	a and *q*.			
	°	″		
1894·347	257·3	97·51		
·350	257·1	96·76		
1894·35	257·2	97·13	− 94″·72	−21″·52
	a and *p*.			
	°	″		
1894·347	43·9	83·65		
·350	43·7	83·56		
1894·35	43·8	83·60	+ 57″·86	+60″·34
	a and *a'*.			
1894·350	189°·5	58″·35	− 9″·63	−57″·55
	a and *d*.			
	°	″		
1894·347	84·1	154·06		
·350	83·9	154 09		
1894·35	84·0	154·07	+153″·23	+16″·10

Following are the measures with the 40-inch :—

a and *q*.

1898·358	257°·33	97″·39		
·375	257·25	97·20		
1898·37	257·29	97·29	− 94″·90	−21″·42

a and *a'*.

1898·375	189°·28	58″·32		
·394	189·60	58·52		
1898·38	189·44	58·42	− 9″·58	−57″·63

a and *d*.

1898·358	83°·85	154″·48		
·375	83·62	154·19		
1898·37	83·73	154·33	+153″·41	+16″·85

a and *i*.

1898·375	72°·24	247″·60		
·394	72·16	248·36		
1898·38	72·20	247·98	+236″·11	+75″·81

These compared with Struve's measures give the following differences, and for further comparison Wilson's measures are also given.

For the star *q*.

		Δα	Δδ	Δα	Δδ
				Differences from Struve.	
	Struve	− 97″·6	−20″·9		
	Wilson	− 94·4	−20·6	−3″·2	−0″·3
1894	Barnard	− 94·7	−21·5	−2·9	+0·6
1898	,,	− 94·9	−21·4	−2·7	+0·7

For the star *a'*.

	Struve	− 12″·3	−57″·2		
	Wilson	− 9·6	−57·5	−2″·7	+0″·3
1894	Barnard	− 9·6	−57·5	−2·7	+0·3
1898	,,	− 9·6	−57·6	−2·7	+0·4

		Δα	Δδ	Δα Differences from Struve.	Δδ Differences from Struve.
	For the star *p*.				
	Struve	+ 60″·6	+ 57″·9		
	Wilson	+ 56·6	+ 60·1	+ 4″·0	− 2″·2
1894	Barnard	+ 57·9	+ 60·3	+ 2·7	− 2·4
	For the star *d*.				
	Struve	+ 152″·5	+ 12″·8		
	Wilson	+ 151·5	+ 16·6	+ 1″·0	− 3″·8
1894	Barnard	+ 153·2	+ 16·1	− 0·7	− 3·3
1898	,,	+ 153·4	+ 16·8	− 0·9	− 4·0
	For the star *i*.				
	Struve	+ 238″·2	+ 71″·5		
	Wilson	+ 232·9	+ 74·3	+ 5″·3	− 2″·8
1898	Barnard	+ 236·1	+ 75·8	+ 2·1	− 4·3

My measures have not been reduced to the epoch of Struve's observations.

These differences certainly imply change of some sort if the early measures can be relied on. But if we examine *Phil. Trans.* vol. 151, part iii, it will be seen that in the observations of these stars very few direct measures of distance were made, the distances being computed from the observed angles along with a few measured distances. This is an unsatisfactory method and liable to many errors. It does not therefore seem certain that these discordances are due to motion in the observed stars.

Yerkes Observatory, Williams Bay, Wisconsin:
1902 March 22.

Notes on Nebulæ observed at the Royal Observatory, Cape of Good Hope.

(Communicated by Sir David Gill, K.C.B., F.R.S., H.M. Astronomer.)

By Mr. J. Lunt.

Five new nebulæ were picked up with the 18-inch telescope during a search for Brorsen's Comet in 1900. Their positions are (1900)—

R.A. h	m	Dec. °	′
22	3·5	−47	40
22	5·2	−46	36
22	8·3	−46	24
22	15·2	−46	34
22	25·5	−46	30

These are near the nebulæ *h* 3924, *h* 3931, and *h* 3932 (N.G.C. 7213, 7232, and 7233).

New (1900) $10^h\ 56^m\ 28^s{\cdot}2$, $-64°\ 42'{\cdot}7$.

A stellar nebula found visually with the 24-inch o.g. prism. Mag. 10–11.

Immediately N.p. C.P.D. $-64°$ 1588.

Spectrum on plate 159 (12/6/1901), chart on plate 164 (14/6/1901).

New (1900) $17^h\ 49^m\ 6^s{\cdot}6$, $-21°\ 47'{\cdot}0$.

A stellar nebula found visually with the 24-inch o.g. prism. Mag. 12–13.

Immediately S.f. C.P.D. $-21°$ 6502. The nebula is $2^s{\cdot}5$ pr. a slightly brighter star of the same declination.

Photographed on plates 178 and 182 (24/6/1901 and 8/7/1901).

By Mr. R. T. A. Innes.

h 2518 (N.G.C. 1269). Not visible in the 7-inch. (3/12/1901.) This is perhaps the same as Δ487 (N.G.C. 1291), observed by *h* on the same night. *h* gives for the latter exactly the same declination and description as for *h* 2518.

Δ487 was well seen on the night that *h* 2518 could not be found.

h 3443 (N.G.C. 4815). It is doubtful if this (which *h* calls a cluster) is resolvable in the 7-inch. It is involved with, but to the S of, the two stars C.P.D. $-64°$, 2088 and 2090. Place of latter (1875), $12^h\ 50^m\ 16^s{\cdot}5$, $-64°\ 16'{\cdot}5$.

h 3546 (N.G.C. 5357). There is no nebula visible in the 7-inch in *h*'s position. There is a small elliptical nebula near two 10th mag. stars at (1860) $13^h\ 49^m{\cdot}8$, $-28°\ 38'$. This is 1° different from *h*'s declination.

New (1875) $13^h\ 28^m{\cdot}6$, $-61°\ 25'$.

This is a small round nebula about 1′ in diameter, brighter towards the centre.

h 3563 (N.G.C. 5530). As seen with the 7-inch. This is a fine nebulous star. *h* has !, vF, pmE, e s v m b M ✱ 12.

Cordoba D.M. $-43°$, 9005. (1875) $14^h\ 14^m\ 30^s{\cdot}8$, $-43°\ 34'{\cdot}2$.

As seen with the 7-inch on 14/8/1901 this is a fine planetary nebula, 10 mag., about 20″ in diameter. Examined

on the same night with the 18-inch telescope, it appeared dumb-bell-shaped. Mr. Lunt, with the 24-inch o.g. prism, found the spectrum to be that of a gaseous nebula. This nebula also appears on several *Carte du Ciel* plates. Plate 3689, with 1^h exposure, shows two very elongated spindle-shaped nebulæ of the same length, parallel to each other, and in contact at their points of greatest condensation or brightness. Angle of elongation = 80°.

The different appearances shown by the different instruments is instructive.

This nebula was also found at Arequipa. See *Harvard Circular*, No. 60, received here 22/8/1901.

New (1875) $17^h\ 34^m{\cdot}8$, $-64°\ 37'$.

A faint oval nebula 1′ in diameter, N. p. η *Pavonis*. Found with the 7-inch.

Royal Observatory, Cape of Good Hope:
1902 *February* 20.

Cape Double Star Results, 1901. By R. T. A. Innes.

(*Communicated by Sir David Gill, K.C.B., F.R.S., H.M. Astronomer.*)

The year generally was unfavourable for double star work. All the measures were made with the Repsold micrometer on the 18-inch refractor. In the cases of a few newly discovered pairs estimates only have been secured: these were generally made with the 7-inch refractor.

It was found that an arithmetical error had been made in the determination of the screw-value used in the reduction of the measures made in 1900. Further observations for the determination of screw-value were also made. A perplexing difference between the value derived from slow-moving stars and from differences of declination has been brought to light. It is shown below:—

1ST METHOD.

Differences of Declination of Stars whose Relative Positions have been Determined with the Heliometer.

Date.	Revs.	Diff. Dec.	Value.	Stars.	Heliometer.
1899 Dec. 2–3–4	14·2993	251·63	17″·598	ζ_1 & ζ_2 Reticuli	Cape
1901 Dec. 13	20·0658	353·76	·605	19 „ 20 Tauri	Yale
„ „ 23	16·4273	288·89	·586	16 „ 20 „	„
1902 Jan. 7	82·9516	1462·28	·610	19 to 27 „	„
„ „ 8	17·0838	300·98	·618	Dist. Atlas & Pleione	„

2ND METHOD.

Transits of Polar Stars.

1901.		Dec.	Value.
Dec. 19	o Octantis	$-88^\circ\ 34'$	$17''\cdot684$
„ 23	„ „	„ „	$17\cdot673$
„ 28	B.A.C. 1960	84 50	$17\cdot655$

As the method of determining double star distances is akin to the 1st method described, the present series of observations has been reduced with the screw-value taken equal to

$$17''\cdot603.$$

To reduce the Cape observations of 1900 to this value they must be diminished by a $\frac{1}{210}$th part, or as follows :—

Distances.	Correction.
$0''\cdot0$ to $1''\cdot0$	$-0''\cdot00$
$1\cdot1$ „ $3\cdot2$	$0\cdot01$
$3\cdot3$ „ $5\cdot4$	$0\cdot02$
$5\cdot5$ „ $7\cdot6$	$0\cdot03$
$7\cdot7$ „ $9\cdot8$	$0\cdot04$
10	$0\cdot05$
20	$0\cdot09$
30	$0\cdot14$
40	$-0\cdot19$

The cause of the discordance between the two methods for finding the screw-value seems obscure, and will be further investigated. It is noteworthy that Otto Struve found a similar discordance at Pulkowa (*Observations*, vol. ix. pp. 18 and 24), viz.

From measured distances	$9''\cdot7091.$
„ transits of stars	$9''\cdot7326.$

He gave his preference to the former value.

The arrangement of the measures will be easily understood. The column "Diff. Mags." is only filled in when actually observed. The colours of the double stars have been frequently recorded. For brevity's sake the following contractions have been used :—

Y = Yellow.	y = yellowish.
B = Blue.	b = bluish.
R = Red.	r = reddish.

o = White.

1–3 = Different shades of yellow.

4–6 = „ „ „ orange.

7–10 = „ „ „ red.

The measures are followed by notes. A separate list of stars examined and not seen double is added. Although some of the latter are certainly double it seemed best to give the list which completes the record of observation. A short list of errata and emendations to the Reference Catalogue of Southern Stars is also included.

[In the references to the *Cape Photographic Durchmusterung* given in the first column, the zone is omitted, as it may be inferred from the column S. Dec. Thus, No. 15, C.P.D. 214 is C.P.D.—63°, 214.]

Professor E. C. Pickering kindly sent lists of new double stars recently found at Arequipa; some of these have since been measured, and the remainder are on the working list.

The observations of *a Centauri*, by Sir David Gill and myself, are given separately. They show that the greatest distance attained is less than the predicted by about 0″·20.

The following casual observations may also be placed on record :—

Lac. 1884	1901 02	204°5	″...	S. S. Hough	1n
Σ 1104	·08	332·1	2·25	J. Lunt	1
Σ 1146	·08	13·2	3·06	„	1

Star.	Mag.	R.A. 1900 h m	S. Dec. 1900 ° ′	1901·+	Pos. Angle. °	Dist. ″	Diff. Mags.	Colours. A.	Colours. B.	No. of Nights.	Remarks.
Harvard ...	5·6	0 1	49 38	90	177·4	5·65	...	...		3–2	1
„ ...	6·4	0 4	54 34	84	294·0	0·73	...	...		1	...
λ 3	8·5	0 5	34 20	94	196·3	1·09	1·0	...		1	...
Innes 43 ...	6·9	0 6	73 47	84	327·2	0·86	...	...		1	2
h 3350 ...	8·2	0 6	58 3	89	179·3	3·32	0·4	...		2	3
β Toucani ...	3·6	0 27	63 31	46	170·7	27·1	0·2	...		2	4
β_2 „ ...	4·3	...	...	58	293·1	0·94	...	...		3–2	5
λ_1 Sculpt. ...	6·1	0 37	39 1	84	321·5	0·54	0·1	...		1	6
Harvard ...	5·7	0 41	48 6	84	304 8	14·4	...	3—		1	7
h 3396 ...	9·4	0 41	33 50	94	221·8	4·31	1·0	...		1	...
Innes 261 ...	7·2	0 43	29 53	84	55·5	...	...	...		1	8
h 3418 ...	9·0	1 2	58 26	89	253·0	2·95	...	...		2	...
Gilliss 9 ...	6·7	1 7	73 29	84	355·3	3·60	3 0	...		1	...
Innes 27 ...	7·3	1 12	69 21	46	204·1	0·95	0·6	4, 4		2–1	...
κ Toucani ...	4·9	1 12	69 24	46	351·6	5·18	...	3,—		2	9
p Eridani ...	5·3	1 36	56 42	03	221·8	7·80	0·3	3·5, 4		2	...
Gilliss 14 ...	7·2	1 39	82 47	03	54·6	5·49	1·2	...		1	...
h 3464 ...	7·8	1 40	76 45	50	158·0	3·09	1·6	...		2	...
Innes 52 ...	8·5	1 43	44 28	97	178·6	0·62	0·3	...		1	...
h 3469 ...	6·4	1 46	38 54	97	351·5	28±	7·6	...		1	10

Star.	Mag.	R.A. 1900 h m	S. Dec. 1900 ° ′	1901·+	Pos. Angle. °	Dist. ″	Diff. Mags.	Colours. A.	B.	No. of Nights.	Remarks.
Innes 265 ...	8·0	1 57	44 19	97	24·6	0·95	1·5	...		1	...
„ 311 ...	8·4	2 2	82 47	04	41·5	1·93	0·7	2·5, B		3–2	11
U.A. 13⅓ Horologii	7·2	2 37	59 59	06	317·5	0·25 ±	0 2	0, 0		4	12
h 3541 ...	8·5	2 50	60 20	41	156·4	2·52	1·3	2, b		2	...
C. Z. 3h 1 ...	8 0	3 1	60 23	08	146·7	0·57	0·2	Y, Y		1	13
Cape 3 ...	9·2	3 5	42 54	06	254·0	2·17	0·6	...		1	...
Innes 54 ...	8·7	3 5	41 45	06	131·1	0 74	0·3	..		1	...
λ 22	8·0	3 8	30 39	06	343·4	1·17	2·0	...		1	14
Innes 55 ...	5·9	3 9	44 48	08	182·3	0 82	0·8	3, 3		2	102
O.A. 2179 ...	8·5	3 14	19 26	08	163·0	3·86	1·5	...		2	...
C.P.D. 214 ...	8·3	3 14	63 39	09	322·2	0·66	0·4	...		1	15
Innes 150 ...	8·2	3 16	63 26	09	358·3	3·80	3·5	...		1	...
χ_3 Fornacis...	6·6	3 24	36 12	95	251·0	6·54	...	—, r		1	...
C.P.D. 570 ...	8·8	3 47	55 39	42	203·2	2·13	0·2	...		2	16
Harvard ...	5·6	3 51	40 39	06	172·8	23·1	6·6	3, —		2	...
Innes 269 ...	7·3	3 59	54 41	40	78·7	3·38	...	...		2	...
„ 152 ...	7·6	4 1	35 43	05	70·5	0·83	0·0	...		1	...
„ 271 ...	7·5	4 19	43 1	40	145·3	2·34	2·3	3·5, b		2	...
Cape 28 ...	9·1	4 34	50 21	03	279·0	6·37	0·4	...		2	...
h 3672 ...	8·3	4 35	35 30	01	300·5	4·23	1·0	—, 4		1	...
a Cæli	4·5	4 37	42 3	41	111·9	5·78	7·2	2, —		2	...
Innes 60 ...	9·0	4 38	45 54	01	95·6	2·33	0·2	...		1	...
h 3696 ...	8·4	4 46	56 11	03	290 8	3·29	0·8	...		2	17
„ AC	...	...	...	05	117·3	9 ±	5·2	...		1	
Cordoba [10]	7·5	4 46	50 3	01	256·3	4·49	3·0	...		1	18
θ Pictoris ...	6·3	5 23	52 24	97	199·3	0·43	0·2	...		1	...
Lac. [1873]	8·5	5 23	58 15	49	103·4	0·48	0·0	Y, Y		2	19
Innes 347 ...	8·0	5 36	75 18	01	129·0	9·06	4·0	...		1	...
„ 279 ...	8·5	5 43	43 18	02	9·4	0·86	0·7	...		1	...
„ 348 ...	9·0	5 49	29 3	08	60 5	4·07	2·0	...		2	20
h 3807 ...	8·3	5 49	41 42	02	273·1	5·07	2·0	4, B		1	...
Innes 16 ...	7·0	5 49	38 33	02	123·1	1·13	4·0	4, b		1	...
Dunlop 23 ...	6·9	6 2	48 27	01	40·1	1·66	0·4	...		2	...
Innes 349 ...	7 0	6 11	29 34	02	44·7	6 96	...	...		1	...
„ 3 ...	6·9	6 12	61 27	50	7·0	0·79	0·4	Y, Y		2	...
Cape 23 ...	8·5	6 12	49 5	01	63·0	4·42	1·0	...		1	...
Innes 281 ...	8·7	6 18	44 45	09	7·3	6·29	1·8	2, 7		2	...
Harvard ...	6·8	6 20	45 35	14	4·0	34·2	3·0	4, b		1	...

Star.	Mag.	1900 R.A. h m	1900 S. Dec. ° ′	1901·+	Pos. Angle. °	Dist. ″	Diff. Mags.	Colours. A.	Colours. B.	No of Nights.	Remarks.
Innes 282 ...	7·7	6 22	50 29	49	314·4	1·44	2·2	y, b		2	...
G Puppis ...	6·0	6 23	48 7	49	133·3	1·18	...	y, b		2	21
Sellors 7 ...	5·3	6 27	50 10	02	...	...	...	...		1	22
10 Canis Maj.	5·1	6 41	30 58	13	97 ±	36·1 ±	5·4	...		1	23
Innes 179 ...	6·9	6 41	30 29	13	226·7	4·49	2·5	3, b		1	...
„ 184 ...	8·5	6 42	64 25	14	236·0	5·96	2·5	2, —		1	...
h 3891 ...	6·0	6 42	30 51	05	224·0	4·59	2·9	1, B		1	...
Innes 180 AB	8·5	6 42	52 19	01	342·8	0·78	0·5	0, 0		1	...
„ AC	...	...	...	01	243·1	42·7	4·5	...		1	...
Innes 351 ...	6·9	6 42	71 40	14	332·1	10·8	3·5	4, -		1	...
„ 157 ...	7·0	6 45	54 35	07	352·4	...	2·5	...		1	...
„ 158 ...	7·2	6 45	48 27	07	185·9	2·06	3·0	2, —		1	24
„ 181 ...	8·0	6 47	44 56	97	254·4	0·79	0·2	...		1	...
„ 182 ...	8·0	6 47	28 36	13	141·4	0·74	0·5	...		1	25
„ 159 ...	6·4	6 47	45 20	14	322·5	6·52	...	6, B		1	...
Cape 19 ...	9·0	6 49	47 38	14	121·4	2·48	0·0	0, 0		1	...
Innes 65 ...	6·3	6 54	35 23	55	200·0	[0·58]	0·1	3, 3		2	26
„ 66 ...	7·7	6 55	35 17	13	253·9	1·80	1·3	2, —		1	...
Harvard AB Lac. 2553 AC	6·7	6 55	30 52	13	9m 35 ± / 10m 70 ±		... / ...	... / ...		1	...
h 3932 ...	7·3	6 59	77 39	13	283·8	8·44	2·0	1, b		2	...
Innes 184 ...	8·0	7 8	60 25	55	182·4	0·81	...	0, 0		2	...
h 3941 ...	6·9	7 8	60 13	97	303·0	0·98	...	4, 4		1	...
Innes 7 ...	7·3	7 15	48 49	55	209·3	0·97	...	4, 4		2	...
C.P.D. 2034	8·7	7 16	21 42	99	275·7	4·95	0·7	...		1	27
h 3996 ...	7·6	7 28	84 17	14	254·8	16·2	3·5	...		1	...
d_2 Puppis ...	5·9	7 36	37 55	97	152·7	1·43	...	...		1	...
C.P.D. 1991	9·0	7 41	30 18	09	1·8	0·88	0·3	...		1	28
ζ Volantis ...	3·8	7 43	72 22	15	116·4	16·6	...	3, B		1	...
Innes 186 ...	7·4	7 45	30 18	54	198·7	1·02	0·2	...		2	...
„ 286 ...	8·6	7 50	47 43	54	292·2	2·54	0·1	0, 0		2	...
h 4023 ...	7·5	7 51	70 31	57	220·2	1·76	0·2	b, 5		2	...
Innes 26 ...	6·7	7 54	47 37	54	30·6	0·85	0·8	3·5, 3·5		2	29
„ 29 ...	8·0	7 55	60 20	98	186·7	3·22	1·3	...		2	30
„ 163 ...	8·2	7 57	40 18	99	135 ±	0·5 ±	...	...		1	...
„ 190 AB	7·7	8 2	54 42	56	118·6	2·45	2·8	1, —		2	...
„ 190 AC	...	...	...	56	143·9	24·0	6·3	...		2	31
„ 165 ...	8·9	8 7	48 54	99	92·8	0·66	0·5	...		1	...
„ 167 ...	8·5	8 12	62 11	13	232·1	1·14	0·5	0, 0		1	...

Star.	Mag.	R.A. 1900 h m	S. Dec. ° ′	1901·+	Pos. Angle. °	Dist. ″	Diff. Mags.	Colours. A.	B.	No. of Nights.	Remarks.
B Velorum ...	4·8	8 19	48 10	99	141·0	0·92	2·5	...		1	32
P viii. 60 ...	6·5	8 19	26 2	40	225±	12±	5·0	...		1	33
C. Z. 8h 2087	8·0	8 26	38 16	40	190±	0·6±	0·3	...		1	34
Innes 313 ...	7·2	8 27	41 11	15	216·7	3·75	...	3, B		1	35
,, 355 ...	8·2	8 32	20 43	99	39·2	0·75	0·3	4, 4		1	...
,, 357 ...	8·4	8 58	23 21	99	178·8	0·69	0·4	...		1	...
Cordoba (21)	8·3	9 6	43 46	61	47·6	2·78	0·9	...		2	41
C.P.D. 1034	8·4	9 16	69 58	30	340±	5±	0·4	...		1	36
Innes 12 ...	5·4	9 18	74 28	09	267·2	0·38	0·4	3, 3		1	...
ψ Argus ...	3·5	9 27	40 2	17	307·2	0·70	0·5	...		2–1	37
Innes 31 ...	9·2	9 28	56 33	62	156·9	3·16	0·3	...		2	...
,, 289 ...	8·2	9 29	73 13	17	257·5	0·79	0·4	...		2	38
,, 200 ...	7·7	9 29	60 48	17	358·0	1·20	2·2	y, b		2	39
,, 201 ...	8·2	9 31	73 18	17	152·1	2·07	2·2	2·5, b		2	...
λ 115	5·5	9 34	53 13	20	180±	0·7±	0·2	Y, Y		1	40
Innes 202 ...	7·0	9 35	39 10	97	176·2	1·58	2·0	3, b		1	...
,, 320 ...	8·6	9 36	66 15	08	49·0	1·04	1·2	0, 0		1	41
,, *321 ...	9·3	9 37	58 49	09	209·8	2·03	0·0	0, 0		1	...
C. Z. 9h 3089	8·5	9 41	37 6	97	340·3	0·72	0·1	...		1	42
Hargrave 28	7·8	9 42	59 1	09	285·1	1·98	2·5	4, b		1	43
Innes 172 AB	7·7	9 43	37 16	97	311·9	1·04	...	...		1	...
,, AC	...	...	...	97	200±	10±	15m	...		1	44
,, AD	...	...	...	97	270±	30±	13m	...		1	...
Innes 204 AB	7·2	9 44	69 39	08	124·3	1·53	2·5	...		1	...
,, AC	...	...	...	08	319·5	3·65	4·0	...		1	45
Cordoba [78]	9·0	9 45	44 26	09	109·4	1·89	0·2	0, 0		1	...
φ Argus ...	3·7	9 53	54 6	28	7·4	37·0	7·8	...		1	46
Innes 322 ...	9·0	9 55	62 5	28	68·0	2·00	0·5	...		1	47
,, 290 ...	9·2	9 59	59 36	09	272·0	2·68	1 2	...		1	...
,, 173 ...	5·2	10 2	46 53	08	61·2	0·3±	2·0	5, 5		1	48
,, 361 ...	8·5	10 9	46 59	28	135·1	4·36	1·8	2, b		1	49
,, 207 ...	8·5	10 14	32 43	28	323·3	{3·49 or 2·62}	0·2	1, 1		1	50
,, 208 ...	7·5	10 20	43 44	22	30·6	0·82	0·8	...		1	51
,, 33 AB	9·3	10 28	61 3	09	41·6	0·65	0·2	0, 0		1	52
,, ,, AB, C ...		...	...	09	116·7	5·07	0·1	0, 0		1	...
Innes 32 ...	9·0	10 28	61 17	09	345·1	5·28	2·0	...		1	...
C. Z. 10h 2838	8·7	10 40	36 21	20	350±	1±	0·6	...		1	53

Star.	Mag.	R.A. 1900 h m	S. Dec. 1900 ° ′	1901·+	Pos. Angle. °	Dist. ″	Diff. Mags.	Colours. A.	B.	No. of Nights.	Remarks.
C.P.D. 3761	8·8	10 42	56 48	50	240 ±	3 ±	0·3	...		1	54
Innes 212 ...	7·0	10 58	81 1	54	151·2	0·61	0·0	4, 4		1	55
„ 295 ...	8·6	11 4	61 0	54	192·2	1·59	2·5	2, —		2	...
„ 213 ...	8·0	11 6	32 1	53	127·1	1·01	2·5	...		1	...
„ 231 ...	7·3	11 8	70 40	54	2·2	2·57	3·2	2, b		2	...
„ 307 ...	8·5	11 35	51 8	53	35·8	0·86	0·2	3, 2		1	...
„ 34 AB	5·1	11 35	64 51	53	234·1	38·1	6·9	4, —		1	...
„ „ AC	...	...	...	53	31·7	42·4	7·4	...		1	55
„ 308 ...	8·5	11 36	49 39	53	128·1	1·33	0·0	Y, b		1	56
„ 215 ...	6·9	11 57	34 6	53	236·7	1·13	0·8	...		1	...
„ 81 ...	9·0	12 10	29 13	54	334·0	2·60	1·5	2, b		1	...
α Crucis ...	1·0	12 21	62 33	67	118·2	4·63	...	...		2	57
Innes 35 ...	8·5	12 21	76 7	54	316·3	2·25	0·3	...		1	58
„ 36 ...	7·7	12 23	61 19	53	324·4	21·7	3·3	...		1	...
γ Centauri ...	2·4	12 36	48 25	73	355·1	1·40	...	...		1	57
β Muscæ ...	3·3	12 40	67 34	67	343·0	1·21	0·3	...		2	57
Ref. Cat. 14 AC	4·7	13 6	59 23	58	257·6	49·8	7·3	...		1	59
Lac. 5431 ...	7·5	13 8	62 7	58	140·1	8·28	3·5	4·5, b		1	60
Cape 32 ...	8·4	13 20	52 46	58	263·1	4·26	0·6	—, r		1	...
C. Z. 13^h 1224	8·8	13 22	42 42	43	153·1	...	1·7	4, b		2	61
λ 180	7·0	13 25	41 57	43	230·6	3·68	2·5	4, B		2	62
C. Z. 13^h 2913	8·5	13 49	42 5	30	50 ±	0·3 ±	0·3	Y, Y		1	63
h 4636 ...	8·9	13 52	39 29	60	33·5	cloud	0·7	...		1	...
Harvard ...	6·4	13 53	65 47	58	196·7	46·0	5·6	...		1	4
Innes 225 ...	7·2	13 54	62 28	58	299·9	2·14	3·5	5, b		1	41
Russell 231 ...	9·0	13 54	66 42	58	163·0	3·86	0·7	3, b		1	41
Sellors 19 ...	6·9	14 1	49 24	58	244·0	0·89	0·2	3, 3		1	65
h 4649 ..	8·3	14 2	59 15	58	246·3	8·36	0·2	6, 5		1	...
h 4667 ...	7·3	14 13	73 6	60	142·5	2·26	0·3	2, b		2	...
Dunlop 159 AB	5·0	14 15	58 0	61	161·7	9·48	...	5, —		1	...
„ AC	...	...	...	61	250 ±	19 ±	...	...		1	66
„ AD	...	...	...	61	4·1	45·4	...	...		1	...
τ_1 Lupi ...	4·4	14 20	44 56	30	185 ±	0·3 ±	0·1	...		1	67
„ ...	...	...	...	58	177·1	...	...	4, 4		1	...
Innes 326 ...	7·2	14 21	75 50	48	121·8	2·30	3·0	5, b		3	...
Bris. 4918 ...	6·3	14 23	67 16	58	193·8	35·2	7·7	...		1	68
Harvard ...	6·5	14 27	52 14	58	180 ±	15 ±	8·5	4, —		1	69
α Lupi ...	2·5	14 35	46 58	58	232·1	27·5	11·5	...		1	70

Star.	Mag.	1900 R.A. h m	1900 S. Dec. ° ′	1901·+	Pos. Angle. °	Dist. ″	Diff. Mags.	Colours. A.	Colours. B.	No. of Nights.	Remarks.
Cordoba ...	8·3	14 37	75 34	58	120·9	11·9	1·5	...		1	71
Innes 368 ...	9·2	14 38	62 25	58	4·0	3·20	1·2	2, b		1	...
h 4695 ...	6·9	14 41	74 31	58	290·2	17·4	4·1	...		1	...
Innes 84 ...	7·5	14 49	36 1	40	260·1	4·07	3·0	—, 7		2	72
„ 237 ...	8·8	14 53	41 33	40	192·6	0·90	0·5	5, 5		2	...
„ 85 ...	8·5	14 59	35 32	27	182·0	1·05	0·5	0, 0		1	...
λ Lupi ...	4·3	15 2	44 54	27	189·7	0·83	0·3	2, 2		1	...
Innes 238 ...	8·2	15 5	44 38	27	141·2	3·30	2·5	2, —		1	55
Harvard ...	7·0	15 9	43 47	41	38·6	13·3	2·5	2, 7		2	...
Innes 86 ...	9·5	15 15	37 54	27	262 2	2·10	1·0	...		1	...
γ Lupi ...	3·0	15 28	40 50	35	95·0	0·74	...	...		2–1	73
C. Z. 15h 2416	9·3	15 36	44 24	66	197·4	1·20	0·6	4, 4		1	74
Innes 334 ...	9·0	15 54	71 37	53	139·8	2·11	2·0	—, 6		1	...
Cordoba [44]	8·3	16 5	56 9	56	131·6	3·17	2·0	1·5, b		2	...
C.P.D. 10015	9·1	16 27	52 27	60	120 ±	2 ±	0·5	...		1	75
C. Z. 16h 2120	8·9	16 32	46 27	70	320 ±	2 ±	0·2	...		1	76
Innes 100 ...	6·8	16 48	73 16	53	180·1	base	1·5	3, 3		1	77
h 4904 ...	7·4	16 57	75 15	59	187 0	7·04	2·0	2, b		1	41
C. Z. 16h 4210	8·7	17 1	41 49	70	90 ±	2·5 ±	0·1	...		1	78
Lac. 7131 ...	7·1	17 1	41 29	70	180 ±	0·8 ±	0·5	5, 5		1	78
Mosta 1541	8·7	17 5	41 52	70	30 ±	5 ±	2·5	...		1	79
Lac. 7177 ...	7·1	17 9	42 14	70	160 ±	1·5 ±	2·0	...		1	80
Brisbane AB	5·5	17 11	46 32	67	77·3	2·17	...	...		3	...
C. Z. 17h 706	8·8	17 12	39 40	70	40 ±	4 ±	2·0	...		1	81
Lac. 7211 ...	7·5	17 12	44 7	64	11·7	0·51	0·1	...		1	82
C. Z. 17h 802	8·3	17 14	42 33	70	280 ±	2·5 ±	1·8	...		1	83
Innes 376 ...	9·0	17 24	65 57	64	37·6	2·17	1·0	...		1	...
h 5014 ...	5·2	18 0	43 25	77	242·3	1·58	0·1	...		1	...
Harvard ...	6·0	18 0	73 41	64	232·1	2·57	3 0	2, 4		2	84
Lac. 7585 ...	6·9	18 5	50 35	66	160·8	2·27	4·0	...		1	85
h 5029 ...	7·2	18 6	57 53	72	109·9	2·39	0·2	2, b		2	86
h 5031 ...	8·0	18 7	47 24	61	82·8	25·7	1·7	...		2	87
Lac. 7574 ...	6·5	18 7	68 16	66	298·3	2·51	3·5	...		1	85
C.P.D. 5842	7·9	18 14	62 38	64	55·4	5·66	0·2	...		3	88
Cordoba [51]	7·9	18 16	42 49	77	138·9	3·60	0·3	...		1	89
C.P.D. 8421	9·3	18 26	42 44	77	45·9	6·54	0·4	...		1	90
κ Cor. Aust.	5·7	18 26	38 48	71	358·7	21·8	0·7	—, 2		2	...
Lac. 7881 ...	7·0	18 45	41 49	60	340·0	34·9	3·5	5, —		2	85

Star.	Mag.	1900 R.A. h m	1900 S. Dec. ° ′	1901 +	Pos. Angle. °	Dist. ″	Diff. Mags.	Colours. A.	B.	No. of Nights.	Remarks
h 5069 ...AB	7·5	18 47	61 57	74	82·9	0·85	0·1	...		2	..
AC	...	...	...	82	93·0	15·3	...	...		1	...
Gilliss 248 ...	8·0	18 48	66 2	66	129·6	4·19	0·2	2, b		2	...
ζ Sagittarii	2·7	18 56	30 1	73	61·9	0·65	0·2	...		4–3	...
Gale	5·6	19 7	66 50	82	39·5	0·82	0·2	...		1	...
λ 382	8·0	19 28	41 38	81	307·3	1·99	0·4	...		2	...
Innes 120 ...	7·0	19 40	62 3	64	152·0	0·72	0·0	2, 2		2	...
h 5148 ...	7·1	19 43	45 38	83	318·0	13·9	4·5	...		2	...
Lac. 8293 ...	6·0	19 53	37 58	83	209·4	22·9	7·5	...		2	91
„ 8300 ...	7·2	19 55	38 51	84	147·1	0·55	0·4	2, 2		2	91
λ 404	6·6	19 59	33 17	85	74·2	0·81	2·0	...		2	92
Lac. 8337 ...	6·5	20 3	57 49	64	227·9	0·67	0·3	2, 2		2	91
„ 8343 ...	6·9	20 6	64 44	68	306·0	17·4	3·1	2, —		2	91
C. Z. 18^h 184	8·5	20 7	62 28	84	281·9	0·83	2·3	...		3	93
Cordoba [57]	7·8	20 14	55 7	84	1·5	4·35	2·0	2, b		2	...
h 5182 ...	6·3	20 17	81 18	84	356·9	26·8	...	3, b		1	..
Innes 41 ...	7·0	20 30	45 54	69	0·8	1·77	1·0	2, b		2	...
„ 17 ...	7·2	20 38	50 51	85	219·5	0·90	0·1	...		1	..
„ 300 ...	8·5	20 41	17 4	85	299·1	3·91	0·1	b, 3		1	...
„ 257 ...	7·8	20 57	76 23	80	293·3	1·51	0·4	...		2	...
Lac. 8625 AB	5·9	20 59	73 34	76	180?	...	...	...		1	94
				85	280?	...	...	...		1	...
AB, C	...	...	...	85	137·4	8·14	...	...		1	...
Brisbane ...	5·7	21 42	47 45	84	359·4	46·6	...	2, 6		2	...
h 5292 ...	9·0	21 47	85 13	85	155·7	5·47	...	...		1	...
Lac. 8939 ...	6·3	21 48	62 21	82	113·1	0·3 ±	...	2, 2		2	95
Cordoba [61]	8·6	21 54	30 28	84	258·7	3·09	...	y, b		2	...
λ 466	8·5	21 59	40 11	81	267·7	2·31	0·6	...		2	...
h 5316 ...	8·0	22 0	56 37	82	141·9	3·83	2·0	2, b		2	...
C.P.D. 6626	8·4	22 6	61 42	85	194·5	5·28	0·2	...		3	96
Lac. 9062 ...	7·3	22 11	68 48	85	89·3	26·7	4·2	...		1	91
π_2 Gruis ...	5·8	22 17	46 26	85	206·7	4·48	...	...		1	...
Innes 383 ...	5·4	22 18	58 18	85	251·1	19·7	9·6	...		1	97
„ 137 ...	6·9	22 21	58 31	85	335·2	...	...	...		1	...
Lac. 9147 ...	6·8	22 25	49 56	76	283·6	19·7	5·2	...		1	98
Cordoba [63]	6·5	22 37	47 43	76	131·6	8·00	...	3, r		1	...
η Gruis ...	4·9	22 40	54 2	76	184·9	23·9	7·6	...		1	...
Sellors ...	8·8	22 59	75 18	79	73·4	3·61	2·5	...		2	...

Star.	Mag.	1900 R.A. h m	1900 P. Dec. °	1901·+	Pos. Angle. °	Dist. ″	Diff. Mags.	Colours. A. B.	No. of Nights.	Remarks.
Sellors AC ...	...	...	...	79·	3·35 ±	25 ±	3·4	...	2	99
Lac. 9444 ...	6·7	23 14	34 15	82	307·0	43·6	5·3	...	1	100
Dunlop 248	6·0	23 15	50 51	82	210·3	16·8	...	...	1	101
Innes 25 ...	7·5	23 30	58 3	79	54·3	0·76	0·1	2, 2	2	...
Lac. 9545 ...	7·0	23 35	47 53	87	66·4	2·05	3·0	2, B	2	91
Innes 146 ...	7·3	23 50	37 55	76	222·6	0·68	1 4	...	1	..

Remarks.

No.

1. Common proper motion of 0″·485. Six small stars near.
2. A 14th mag. 360° ± 20″ ±.
3. Is C.P.D. −57° No. 7. *h* has 173°·6.
4. South star *decidedly* fainter and yellower. This difference of magnitude is in accordance with all the other observations, excepting those of the Southern Meridian Photometry, which makes the southern star 0·17 mag. brighter.
5. Angle has decreased about 27° in five years.
6. This fine pair was discovered at Arequipa and communicated by Professor Pickering. Bailey gives 1896·0. Possibly elongated 90°. Motion?
7. The proper motion of the chief star is 0″·181 towards 70°·6.
8. Fairly accordant angles, but elongation not sure.
9. This is a highly coloured pair. Once the comp. was called "red-brown" and once "purplish."
10. This is not the *h* companion, which has only been seen by *h*, and, he remarks, "must be verified." The companion measured was noted by Mr. Clymer at Arequipa in 1899, and communicated by Professor Pickering.
11. The p. m., if any, is very small.
12. Found with the 18-inch telescope = Innes 386. This is the following of two nearly equal mag. stars, the pr. being 7·0 mag., colour yellow 3. The close pair is white. As a wide pair this is certainly *h* 3525, with an error of 1° in *h*'s declination. *h* 3525 was not found at the Sydney Observatory in 1879. *h* 1836·8, 274°·3, 35″·1, 0·0, 1n.
13. Found with the 18-inch telescope = Innes 387.
14. Wrongly identified by the λ observers. It is O.A. 2112.
15. Found with the 18-inch telescope = Innes 388.
16. ,, ,, ,, ,, 389.
17. The faint companion was added with the 18-inch, with which it is very difficult. The *h* pair is in certain motion, 24° in 67 years—probably due to pr. motion in one of the components.
18. The chief star has been measured as λ 40, dist. = 0″·43—now certainly single.
19. Found with the 18-inch telescope = Innes 390.
20. Two 12th mag. stars, 3″ apart, are 1′ N.
21. P.m. = 0″·03 towards 270°.
22. In the reference catalogue of southern double stars the measures of this star as a triple are given. Bailey (*Harvard Annals*, xxxii. pp. 300, 308) remarks that it is a quadruple. It was observed here on one night, C−D 105°·1, 0″·3 ±, d.m. 0·1, elongation perhaps doubtful, star bluish. At the same time it was noted that in A−B the smaller star (0·1 mag.) is *following*, both stars yellow.
23. From the Harvard list. Angle and distance only roughly taken; still the latter is certainly nearly correct. Bailey has 15″ ±.

No.

24. The proper motion is insensible.
25. Three faint stars about 60″ N. ±.
26. The distances are certainly too great, stars only slightly elongated. This pair was found with the 7-inch in 1896. The measures and estimates are:

	°	″	
1896·9	150 ±	0·6 ±	Innes.
1897·3	160 ±	...	„
1898·3	190·3	0·26	See.
1900·5	188·7	0·25 ±	Innes.
1901·5	200·0	0·4 ?	„

The increase in angle is about 10° per annum.

27. The chief star of a little cluster. C.P.D. mag. = 8·4, B.D. = 9·0. New? = Innes 391.
28. Found with the 18-inch telescope = Innes 392.
29. Evidently fixed. Several very faint stars near.
30. There is a 12th mag. pair 2′ N. pr.
31. New.
32. Proper motion = 0″·02 towards 270°. The measures agree with the estimates made four years ago.
33. Found with the 7-inch telescope = Innes 393. The p.m. is insensible. Near Hough 526.
34. Found with the 7-inch telescope = Innes 394. This star is the N.f., and brightest of a group of three stars.
35. A 13th mag. star is 30″ ± pr.
36. New = Cape 33. Found by Mr. R. T. Pett at the transit circle.
37. Present increase of angle = 1·5° per ann. The period will be about 24 years. Is difficult to measure, distance diminishing.
38. A 14th mag. star, 38″. 6°.
39. A 13th mag. star, 30″ N. pr.
40. Estimated with the 7-inch.
41. Several faint stars near.
42. Found with the 18-inch = Innes 395.
43. The only measure found of this pair. A very minute double star, 20″ pr., a little S.
44. C and D were added with the 18-inch.
45. C added with the 18-inch. The p.m. of A is very small.
46. The faint companion was picked up at the 7-inch = Innes 396.
47. Some very faint stars within 20″.
48. The p.m. is 0″·11 towards 116°. Binary system.
49. This is C. Z. 10^{h} 591, and is the N. pr. of two stars. Original identification erroneous.
50. MS. of number of revolutions of micrometer equivocal; one of the two distances will be correct.
51. A 12th mag. star 30° ± 15″ ±.
52. The close pair is new; added with the 18-inch.
53. Found with the 7-in. = Innes 397. Lac. 4437, mag. 6·8, is 3½′ S.
54. „ „ „ 398.
55. The p.m. is very small.
56. Pr. star yellow, following star bluish. There are two faint comites:

13^{m}	45° ±	10″ ±
12^{m}	30° ±	25″ ±.

57. Taken in sunshine.
58. Colours slightly contrasted.
59. Chief star = λ 170 not seen double, but definition not very good. The distant star alone seen also at Harvard. Many faint stars about; one, 15^{m} N., is closer than the star measured.

No.

60. Found with the 7-inch = Innes 399. There is an 11^m star 60″ due S.
61. Found with the 7-inch = Innes 400. The distances, viz. 4″·60 and 5″·56, are discordant; a 3rd observation must be taken to see which is correct. There is a 14th mag. star 15″ p^f. C.Z. 13^h 1221, mag. 9·1 is closely N. pr.
62. A 15th mag. star is at 12″ ± 83° ±, and there are two brighter stars 20″–30″ distant, one N., one S.
63. Found with the 18-inch = Innes 401. C.Z. 13^h 2915 mag. 9·1 is closely N.f., and with C.Z. 13^h 2913 forms *h* 4625.
64. Many faint stars about, a 15th mag. 46″ ± 317° ±.
65. Considerable change shown. Common p.m. of 0″·134 towards 338°·7.
66. New, 15th mag. too faint to measure.
67. New, found with the 18-inch = Innes 402. The p.m. is under 0″·01.
68. This very difficult companion was measured whilst making an attempt (unsuccessful) to see the three comites to the chief star found at Arequipa by Professor W. H. Pickering. The p.m. of the chief star is 0″·06 towards 180°.
69. Too faint to measure.
70. The p.m. of the chief star is 0″·044 to 229°·1.
71. A 13th mag. star completes a neat triangle. The distance derived from the Cordoba meridian observations seems to be too small.
72. An 11th mag. star 20″ ± N.f.
73. The distance is probably too great. There is no certain change in this pair since 1897.
74. Found at the 7-inch = Innes 403. Mag. taken from Cordoba D.M. C.Z. has 8·0^m, which is more likely.
75. Found with the 7-inch = Innes 404.
76. „ „ „ 405. There is an unrecorded 9^m·5 star 2′ N., not in any D.M.
77. The p.m. is under 0″·04.
78. Both found with the 7-inch = Innes 406 and 407.
79. Found on a *Carte du Ciel* plate by Mr. R. Woodgate, = Cape 34.
80. Found with the 7-inch = Innes 408.
81. „ „ = „ 409. The N. star of a triangle.
82. Found at Arequipa and communicated by Professor Pickering. Mr. Clymer gives 1899, 350° ± 0″·6 ±. A fine pair.
83. Found with the 7-inch = Innes 410. C.Z. 17^h No. 808, mag. 8·6, is 5 secs. following.
84. This fine pair has a common proper motion of ″·231 towards 195″·3.
85. Found by Professor Bailey and communicated by Professor Pickering.
86. Faint star near.
87. On the occasion of the 2nd measure the chief star was suspected to have a close companion S. pr.
88. Fonnd by Mr. R. T. Pett at the Transit Circle = Cape 35. Colours slightly contrasted. In a triangle of faint stars, with many very faint stars interspersed.
89. Two faint stars N. and S.
90. Found on a photo-plate by Mr. Woodgate = Cape 36. There is a 12^m star 90° ±, 15″ ± (18-inch).
91. Found at Arequipa by Mr. Clymer and communicated by Professor E. C. Pickering.
92. A 12^m, 83° ± also seen.
93. Found with the 18-inch = Innes 411.
94. Elongations very doubtful; this pair must be in very rapid motion.
95. Communicated by Professor Pickering. Mr. Clymer at Arequipa gives 1899, 105° ± 0″·5 ±. My settings were quite independent, but at no time was the elongation over-certain.

Proper motion in α: no material.
„ „ $\delta = -0''.08$.

No.
96. Found by Mr. R. T. Pett at the transit circle = Cape 37.
97. These measures were very hard to get—little better than estimates.
98. Found at Arequipa by Mr. Clymer. The p.m. of the chief star is 0″·22 towards 222°·2.
99. Added with the 18-inch.
100. Single distances, clouds, difficult. Found at Arequipa by Mr. Clymer.
101. Common proper motion of 0″·044 towards 154°·7.
102. This triple system—although showing no great change—has a common proper motion of 0″·08 towards 112°·0.

α Centauri.

These measures were taken with the Repsold micrometer on the 18-inch refractor.

Date.	Pos. Ang.	Distance.	Observer.	Number.	Telescope.
1901·07	210°·5	21″·74	Gill	5–4 days	E.
·07	210°·7	·74	Innes	11 „	W.
·26	210°·6	·76	„	4 nights	W. and E.
·59	210°·7	·76	„	6 „	„
·87	210°·7	·67	„	6 days	„

Each measure consists of four settings for position angle and of four double distances for distance.

The means for the previous year (reduced to the same value of the micrometer screw = 17″·603) are :

1900·34	210°·2	21″·72	Innes	18–19 days. &c.
·35	210°·5	21·67	Lunt	17 „

The progressive and periodic errors of the screw have been determined; the former are given in *Monthly Notices R.A.S.*, vol. lxi. p. 613; the periodic errors are also very small, and are given with accuracy by the expression

$$\begin{matrix} R & & R \\ -0''{\cdot}00028 \cos u & -0''{\cdot}00022 \sin u \\ -0''{\cdot}00008 \cos 2u & +0''{\cdot}00004 \sin 2u \end{matrix}$$

The measured distances of *α Centauri* have been increased by 0″·01; half of this is due to the screw errors, the remainder to refraction.

The following stars from various double star lists were observed as single—generally on one night only—so that it is only in a few cases that a definite conclusion has been reached. It was considered on the nights of observation that the definition was sufficiently good to show the duplicity if the star was really double in the sense of previous observations, but, as every observer knows, some nights are not as good as they seem to be. The

greater number of the stars will be further examined. This list completes the record of observation.

Star.	Mag.	R.A. 1900. h m	S. Dec. ° ′	Date of Observ. 1901·+.	Remarks.
κ Phenicis ...	3·9	0 21	44 14	82	Not seen double. See has 13th mag. 8″ in.
α „	2·4	0 21	42 51	82 and 94	Is λ 6, 13th mag. 9″·7 6n. Not seen double. On the second occasion the bright star was kept outside the field.
λ 30 ...	6·7	3 42	54 35	01	Certainly single. This is the chief star of *h* 3592, which has a com. p.m. of 0″·065 towards 23°·5.
α Columbæ ...	2·7	5 36	34 8	02	Not seen, good.
Innes 162 ...	7·5	7 53	52 38	99	Single.
„ 169 ...	7·2	9 7	42 52	09	Single.
„ 203 ...	8·2	9 36	62 6	09	Single. (Found 1897 May 21, and confirmed 1897 May 28.)
Lac. 4096 ...	8·0	9 51	70 59		This was found to be double at the 7-inch 1901·4, 260° ±, 1″ ± companion = 11ᵐ, but on 1901·97 the small star could not be seen with the 18-inch.
Innes 176 ...	9·6	11 1	46 53	53	No companion seen.
λ 145 ...	6·4	12 5	37 19	54	Round, under ½″ if double.
Innes 309 ...	7·7	12 26	77 38	54	Not seen. (Seen *twice* in 1898.)
„ 219 ...	8·5	12 26	55 34	54	Not seen.
Harvard ...	6·2	14 38	55 11	58	The nearest *comes* seen to this star is due f. = 90°, and is much nearer Bris. 5026 than Lac. 6057. Bris. 5026, colour 6.
Innes 226 ...	7·0	14 48	33 44	27	Not seen; hazy.
Lac. 6847 ...	6·8	16 29	72 6	59	Not seen, but definition not good. This is a very difficult pair found by Professor Bailey and communicated by Professor E. C. Pickering.
λ 321 ...	7·0	17 8	39 39	74	Single.
λ 330 ...	8·7	17 24	30 11	70	Single; a faint comes is 30″ pr. Professor See's measure may be transferred to the double star 1ᵐ 23° f. and 2″·2 S. = OA 16867.
Lac. 7561 ...	6·9	18 5	63 43	66	No companion seen. Professor Bailey has 13ᵐ·2, 19″ ±. Chief star, colour orange = 5.
δ_1 Telescopii	5·1	18 24	45 59	66	Not seen double, fair definition. Professor Bailey has 1894·7, elongated.
λ 359 ...	7·7	18 40	43 53	81	Probably single.

Star.	Mag.	R.A. 1900. h m	S. Dec. 1900. ° ′	Date of Observ. 1901·+.	Remarks.
λ 359 ...				82	Single; good definition. Neighbouring stars also single.
λ 373 ...	9·0	19 19	42 5	80	Single; several neighbouring stars also examined.
λ 387 ...	6·7	19 33	42 30	80	Single.
λ 403 ...	7·2	19 57	36 20	84	Neither *comes* seen.
Innes 124 ...	7·7	20 9	63 28	84	Certainly single. This star has been struck out of the list of double stars.
„ 127 ...	9·0	20 27	44 51	85	Single. Seen *twice* in 1896 and measured once in 1900.
„ 131 ...	9·0	21 15	52 12	76	Not found; good search. This star has now been struck out of the list.
λ 494 ...	8·9	23 36	34 45	82	Not seen double.
λ 499 ...	8·1	23 55	40 45	79	Not seen double (two nights).

Errata, &c., in the Reference Catalogue of Double Stars.

Ref. h	Cat. No.	
0	14	*h* 3362. This star and several others observed by *h* in the same sweep require a correction of +1ʰ in R.A. *h* 3362 is thus the same star as *h* 2043 = Ref. Cat. 1ʰ No. 24.
4	53	This is also P. iv. 230. Although a wide pair (14″) there is a common proper motion of 0″·11 towards 328°·0.
7	97	The chief star is V Puppis.
8	22	This is C. Z. 8ʰ 758, mag. 8·6. $\alpha = 8^h\ 10^m\ 15^s$ $\delta = -37°\ 22'·5$.
	45	This is C. Z. 8ʰ 2233, mag. 7·8. $\alpha = 8^h\ 27^m\ 37^s$ $\delta = -36°\ 21'·2$.
9	38	This is Lac. 3833, mag. 6·0. $\alpha = 9^h\ 22^m\ 23^s$, $\delta = -28°\ 21'·2$.
13	53	This wide pair has a common p.m. of 0″·154 towards 270°·0.
17	70	Identity correct as printed.
18	92	This is ν_1 Sagittarii, as pointed out by Professor See. The p.m. is 0″·043 towards 243°·8
19	18	Identity correct as printed.
20	52	This 18″ pair has a common p.m. of 0″·24 towards 131°·0.
21	39	*For* 8826 *read* 8626.

To these may be added the corrections published by other observers; *e.g.* see Mr. Cogshall's lists, *Ast. Jour.* Nos. 505–6.

Errata in Cape Double Star Results, 1900 (*Monthly Notices*, vol. lxi. No. 9).

Page 581, middle, *for* 10° ± *read* 150° ±.
„ 582, lines 6–7, lower *h* 3646 one line.
„ 585, line 3, *for* ″·11 *read* 9″·11.
„ 588, „ 20, *for* ... (1st col.) *read* 80.
„ 592, No. 29, *for* ω (omega) *read* o (omicron).
„ 593, line 17, No. 67, insert semicolon after "referred to."
„ 595, „ 2, „ 32, *for* Obs. L. *read* Obs. L. and I.
„ 599, „ 4, *for* 5859 *read* 5898.
„ 600, No. 93 AC 1900·37, *add* mag. 10·5 new.
„ 609, line 7, *for* "Found" *read* "Observed."

Royal Observatory, Cape of Good Hope:
1902 *January* 14.

Results of Double Star Measures with the 8-inch Equatorial at Windsor, New South Wales, in 1901.

By John Tebbutt.

Ref. No.	Star.	Observed Magn.	Approx. Place of Star 1901·0. R.A. h m	Dec. S. ° ′	Fraction of Year.	Position Angle. °	Distance. ″	No. of Obs.	Mag. Power.	Eyes.	Hour-Angles. h m	h m	Weight 1 to 5.
1	β Phœnicis	5, 5	1 1·7	47 15	·975	18·8	1·41	10–6	300	P	3 6 W	3 29 W	3
2	,,	5, 5	,,	,,	·980	18·1	1·51	10–7	300	P	2 49 W	3 13 W	
3	κ Toucani	5, 8	1 12·4	69 24	·980	350·9	5·66	10–10	300	P	3 20 W	3 51 W	
4	,,	5, 8	,,	,,	·983	354·0	...	10	300	R			
5	,,	...	,,	,,	·983	354·2	...	10	140	R	1 34 W	2 32 W	2
	,,	...	,,	,,	·983	352·0	...	10	300	P			
7	Lac. 1889	6, 6½	5 28·1	42 22	·309	168·7	7·66	10–6	300	P	3 25 W	3 49 W	3
8	Σ 3784	6, 8½	5 35·4	46 9	·282	59·3	5·66	10–4	140	P	3 38 W	...	3
9	Σ 3789	8, 8½	5 36·6	50 11	·309	359·5	9·25	10–6	140	P	3 55 W	4 17 W	3
10	Σ 3823	8½, 8½	5 56·7	31 3	·263	113·8	2·85	10–6	300	R	3 44 W	4 23 W	3
11	,,	8½, 8½	,,	,,	·266	110·6	2·92	10–6	140	R	1 48 W	2 20 W	3
12	Σ 3834	6, 9	6 1·8	45 5	·263	227·9	3·77	10–7	300	P R	2 53 W	3 23 W	4
13	,,	5, 9	,,	,,	·277	230·1	3·73	10–5	300 / 140	P	3 43 W	4 12 W	3
14	Lac. 2145	6, 6½	6 2·2	48 27	·260	37·7	1·89	10–7	300	P	4 24 W	4 51 W	4
15	,,	...	,,	,,	·263	42·4	1·77	10–7	300	R	2 8 W	2 43 W	5
16	,,	...	,,	,,	·266	42·0	...	9	300	R	2 27 W	...	3

Ref. No.	Star.	Observed Mags.	Approx. Place of Star 1901·0 R.A. h m	Dec. S. ° ′	Fraction of Year.	Position Angle. °	Distance. ″	No. of Obs.	Mag. power.	Eyes.	Hour-Angles. h m	h m	Weight 1 to 5.
17	Lac. 2145	...	6 2·2	48 27	·277	39·1	2·04	10–7	300	P	2 59 W	3 29 W	4
18	Lac. 2224	8, 9	6 11·6	61 27	·279	185·3	1·41	10–5	300	P	3 0 W	3 27 W	3–4
19	Lac. [2275]	7, 8	6 11·9	65 30	·279	116·9	21·13	10–7	140	P	2 22 W	2 51 W	3
20	Lac. 2402	5, 8	6 36·0	48 8	·279	320·3	13·63	10–6	300	R	3 18 W	3 46 W	3
21	*h* 3891	5½, 8	6 41·7	30 51	·309	224·7	4·87	10–7	{535 / 140}	P	3 53 W	4 18 W	3–2
22	γ Piscis Vol.	5, 8	7 9·6	70 20	·288	299·1	13·54	10–6	140	P	2 29 W	2 51 W	3
23	Lac. 2779	6½, 7	7 18·0	52 8	·288	21·5	9·99	10–7	140	P	2 57 W	3 17 W	3
24	*h* 3960	6, 7	7 18·6	48 20	·288	156·3	22·86	10–5	140	P	3 31 W	3 54 W	4
25	*h* 4414	5, 9	11 8·3	59 47	·249	217·7	(1·5)	10	300	P	3 1 E	2 34 E	3
26	„	4, 11	„	„	·252	217·3	...	3	300	P	1 2 E	0 41 E	4
27	„	5, 9	„	„	·260	221·5	...	10	300	P	2 23 E	2 0 E	4
28	*h* 4423	6½, 6¾	11 11·9	45 21	·236	276·7	1·62	9–6	300	R	2 20 E	1 52 E	3
29	„	...	„	„	·238	276·9	2·34	10–7	300	R	2 33 E	2 7 E	4
30	*h* 4432	5, 6	11 19·1	64 25	·238	299·2	1·87	10–5	300	R	1 59 E	1 35 E	3
31	„	5½, 7	„	„	·241	297·8	2·52	10–7	300	R	3 16 E	2 50 E	4
32	Brisb. 3574	8, 8½	11 20·4	61 6	·249	25·7	2·07	10–6	300	P	2 23 E	1 46 E	4
33	„	7, 8½	„	„	·252	26·9	1·69	10–6	300	P	1 45 E	1 23 E	4
34	Dunlop 109	5, 8	11 23·8	42 8	·249	167·1	13·32	8–3	300	P	1 28 E	1 5 E	3
35	„	5, 7	„	„	·252	167·0	13·20	10–6	300	P	2 53 E	2 26 E	3

Ref. No.	Star.	Observed Mags.	Approx. Place of Star 1901·0. R.A. h m	Dec. S. ° ′	Fraction of Year.	Position Angle. °	Distance. ″	No. of Obs.	Mag. power.	Eyes.	Hour-Angles. h m	h m	Weight 1 to 5.
36	N. Hydræ	4½, 4½	11 27·4	28 43	·255	211·3	9·35	10–7	300	R	2 22 E	1 58 E	4
37	„	5, 5	„	„	·257	212·2	9·05	10–6	300	R	2 26 E	1 58 E	3
38	*h* 4455	5, 7½	11 31·7	33 1	·255	244·8	3·82	10–5	300	R	1 50 E	1 26 E	3
39	„	5, 7	„	„	·257	245·4	3·75	10–6	300	R	3 42 E	3 17 E	4
40	β Hydræ	5, 5½	11 47·9	33 21	·255	353·0	1·77	10–7	300	P	3 17 E	2 55 E	4
41	„	5, 5½	„	„	·257	350·5	1·60	10–7	300	P	3 23 E	2 53 E	4
42	„	...	„	„	·260	351·0	1·73	10–7	300	P	3 41 E	3 17 E	4
43	ε Chamæl.	5, 7	11 54·7	77 40	·255	187·0	1·59	10–7	300	P	4 11 E	3 39 E	2
44	„	6, 6½	„	„	·260	186·8	1·57	10–7	300	P	2 26 E	1 59 E	5
45	β Muscæ	...	12 40·2	67 34	·222	343·1	1·57	10–6	300	R	2 11 E	1 37 E	3
46	„	...	„	„	·225	342·9	...	10	300	P	3 43 E	...	1
47	„	...	„	„	·236	347·1	...	10	300	P	4 44 E	4 3	
48	„	...	„	„	·236	344·4	...	10	300	P			
49	„	5, 5	12 40·2	67 34	·241	341·7	1·42	10–6	535	P	3 57 E		
50	*h* 4634	...	13 50·7	55 33	·222	26·6	14·55	10–6	140	P	4 8 F		
51	„	...	„	„	·241	26·2	...	6	300	P	4		
52	„	...	„	„	·241	27·0	14·31	10–6	140	P			
53	α Centauri	...	14 32·9	60 25	·975	210·3	21·60	10–10	140	R			
54	θ Gruis	5, 8	23 1·3	44 3	·975	27·3	1·46	10–5	300				
55	„	5, 8	„	„	·980	30·0	1·62	10–5	300				

Remarks.

1, 2, 10, 37, 46, 49, the components were noted as equal. 13, principal component orange, companion blue. 18, the north component was noted as the brighter, but according to Innes' Reference Catalogue, Sellors made the south component the brighter. 20, 31, 38, principal components yellow, companions blue. Innes' Catalogue gives both components of 31 as yellow, and it would appear from the same authority that various colours have been assigned to the companion of 38. 22, both components orange. In 1888 and February of the current year the companion was noted by me to be blue. 25, observations very difficult: the distance is estimated. 26, I had doubts as to the actual existence of the companion, and thought it might possibly be a thickening of the diffraction ring at the spot. The companion 10 mag. measured by Pollock in 1889 not seen. 27, Herschel and Pollock's companion not seen. 36, the north following component was the brighter. 39, principal component orange, companion blue. 40, 41, 42, the south component slightly the brighter. 50, companion blue. 51, 52, principal star white, companion blue. 54, 55, companion pale blue.

The last four columns of the table have been repeatedly explained in previous publications of my double-star results.

Observatory, Peninsula, Windsor, N.S. Wales:
1902 February 24.

Erratum in Double Star Measures, Monthly Notices, vol. lxi. p. 504:

Opposite to ref. No. 55 and under "No. of Obs." *for* 10–6 *read* 10–10.

The Parallax and Proper Motion of graphs taken at the Royal Obser

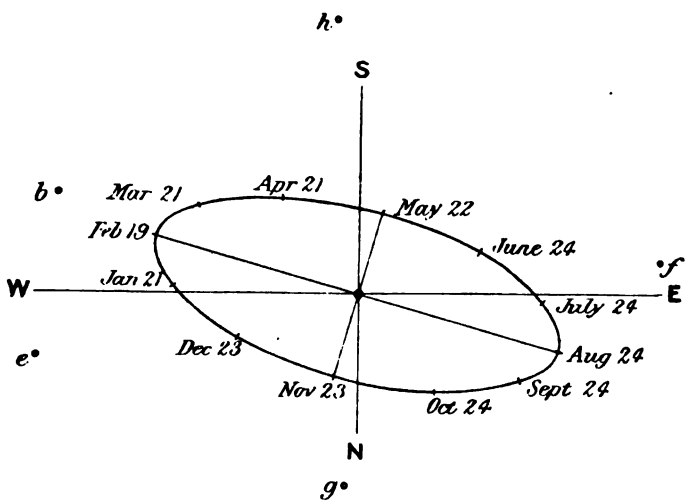
(*Communicated by the Astronomer*

Photographs of Nova *Persei* have been Astrographic Equatorial at intervals from 1901 F earliest date on which it could be observed at G. the present time. Twenty of these photographs measured for the determination of parallax and proper in R.A. and six for the proper motion in declination. distances of the Nova from the three stars *e*, *b*, *f* were measur for the displacement in R.A., and *g* and *h* for that in Dec.

The positions and magnitudes of these reference stars are :—

Mag.	No. in B.D.	B.A. 1900.	Dec. 1900.	Distance and Pos. Angle from Nova.
	°	h m s	° ′ ″	′ °
e 9·1	43, 731	3 21 34·92	43 38 39·2	31 280
b 7·7	43, 732	3 21 46·67	43 24 21·3	30 252
f 9·2	43, 757	3 27 3·65	43 30 45·2	29 96
g 8·8	43, 740	3 24 17·62	43 51 57·9	18 356
h 9·2	42, 773	3 24 10·66	43 7 24·2	26 186

The right ascensions and declination for 1900·0 are taken from Mr. Bellamy's paper in the *Monthly Notices*, vol. lxi. March.



The positions of these stars relatively to the Nova are shown on the diagram, and for convenience the form and position of the parallactic ellipse are given, but necessarily on a greatly magnified scale.

The measurement was made by comparison with a glass scale divided to millimetres: two microscopes are carried on the same slide; one of these is set on a division of the scale by a screw moving the slide, and the image of the star is bisected by the micrometer of the second microscope. The screw of this micrometer has three revolutions to the millimetre. For bisecting the star image parallel wires are used, which can be set at any distance apart. For the early photographs where the image of the Nova was very large the wires were set at 0·50 rev. (= 10″) apart, for the later photographs 0·20 rev. (= 4″). In making the measures the following precautions were taken:

(i.) Each distance was measured in a direct and reversed position of the plate.

(ii.) The same divisions of the scale were used for all the photographs.

(iii.) Each image was bisected twice, the right-hand microscope being set on consecutive divisions of the scale. Each pair of bisections thus furnishes a determination of the runs of the micrometer.

(iv.) The same parts of the screw were used on all the photographs.

(v.) The photographs were measured in duplicate by Mr. Dyson and Mr. Davidson.

The following table gives the measured distances (corrected for refraction and aberration) *ne*, *nb*, *nf*, *ng*, *nh*, and *ef*, the last named being measured to test the constancy of the scale and as a check on the results.

Date.	Z.D.	*ne*. 1862″·57.	*nb*. 1803″·68.	*nf*. 1742″·61.	*ng*. 1098″·14.	*nh*. 1585″·44.	*ef*. 3603″·32.
1901.	° ′	″	″	″	″	″	″
Feb. 28	52 1	+·27	+·24	−·11	−·22	+·10	+·08
Mar. 3	33 53	+·40	+·10	−·18	−·22	+·07	+·07
12	39 9	−·04	−·18	+·01	+·09	+·01	−·02
Apr. 18	69 30	−·14	−·07	+·26			+·28
21	66 13	+·35	+·42	−·32			+·19
23	64 40	−·04	+·34	+·03			−·16
25	66 41	+·25	+·40	−·07			+·14
27	68 10	+·24	+·13	−·25			+·01
30	68 55	+·07	+·23	+·10			+·21
May 8	74 10	+·15	+·03	−·07			+·11
Aug. 10	34 25	−·34	−·25	+·52			+·30
23	57 33	−·13	−·08	+·19			·00
26	55 25	−·12	−·24	+·18			+·15
Sept. 21	42 10	−·33	−·36	+·06			−·47
Dec. 6	17 9	−·14	−·22	+·06			−·08
1902.							
Jan. 6	37 50	−·13	−·17	−·12			−·15

Date. 1901.	Z.D.	*ne.* 1862″·57.	*nb.* 1803″·68.	*nf.* 1742″·61.	*ng.* 1098″·14.	*nh.* 1585″·44.	*ef.* 3603″·32.
	° ′	″	″	″	″	′	″
Jan. 24	29 3	+·21	+·13	−·16			·00
Feb. 9	21 45	+·09	−·04	−·03	+·10	−·11	−·06
9	24 0	·00	+·02	+·03	+·19	·00	·00
12	26 29	−·62	−·43	−·15	+·06	−·08	−·49

In the above table it should be noticed that *ne* and *nb* are on the same side of the Nova, in position angles only 28° apart, while *nf* is on the opposite side, so that if the Nova has any motion in right ascension *nf* should increase as *ne* and *nb* decrease. Similarly *ng* and *nb* are in nearly opposite directions north and south. The changes of scale indicated by the measures of *ef* are small, and in some cases the figures only represent the accidental error of measurement. The two days, September 21 and February 12, seem abnormal, and the photographs are on this account open to some suspicion. They have been carefully examined, and nothing has been found wrong in the measurement or in the photographs themselves.

In forming the following table the scale of each photograph has been corrected so as to make *ef* equal to its mean value, 3603″·32. The right ascension is determined from the three stars *e*, *b*, *f*, and the declination from *ng* and *nh*.

The right ascension deduced from the three stars *e*, *b*, *f* and the declination from the two stars *g* and *h* are :

R.A. 1900·0.	Epoch.	Declination 1900·0.	Epoch.
$3^h\ 24^m\ 24^s·199$	1901·58	43° 33′ 42″·41	1901·64

The following table gives the separate determinations of R.A. and Dec. of the Nova:

Date. 1901.	Seconds of R.A. From *ne.* 24ˢ·203.	From *nb.* 24ˢ·164.	From *nf.* 24ˢ·230.	Mean. 24ˢ·199.	Seconds of Dec. From *ng.* 42″·02.	From *nh.* 42″·82.	Mean. 42″·41.	Pos. of Instrument with respect to Pier.
	ˢ	ˢ	ˢ	ˢ	″	″	″	
Feb. 28	+·021	+·017	+·014	+·017	+·24	+·06	+·15	E.
Mar. 3	+·032	+·006	+·019	+·018	+·24	+·04	+·14	E.
Mar. 12	−·003	−·015	−·002	−·007	−·09	·00	−·04	E.
Apr. 18	·025	−·018	−·011	−·018	...	...	...	E.
Apr. 21	+·023	+·029	+·037	+·030	...	...	...	E.
Apr. 23	+·004	+·038	−·010	+·011	...	...	...	E.
Apr. 25	+·016	+·029	+·013	+·019	...	...	...	E.
Apr. 27	+·021	+·011	+·023	+·018	...	...	...	E.
Apr. 30	−·004	+·011	·000	+·002	...	...	...	E.
May 8	+·008	−·002	+·011	+·006	...	...	...	E.
Aug. 10	−·040	−·030	−·038	(−·036)	...	...	...	W.
Aug. 23	−·012	−·007	−·017	−·012	...	...	...	W.

Date.	Seconds of R.A. From *na.* 24ʰ·203.	From *nb.* 24ʰ·164.	From *nf.* 24ʰ·230.	Mean. 24ʰ·199.	Seconds of Dec. From *ng.* 42″·02.	From *nA.* 42″·82.	Mean. 42″·41.	Pos. of Instrument with respect to Pier.
1901.	s	s	s	s	″	″	″	
Aug. 26	−·018	−·027	−·010	−·019	...	...	...	W.
Sept. 21	−·008	−·011	−·026	−·015*	...	...	...	W.
Dec. 6	−·009	−·016	−·009	−·013	...	...	...	W.
1902.								
Jan. 6	−·005	−·009	+·005	−·003	...	...	...	E.
Jan. 24	+·019	+·011	+·014	+·015	...	...	...	E.
Feb. 9	+·011	−·001	−·000	+·003	−·12	−·08	−·10	E.
„	·000	+·002	−·003	·000	−·19	·00	−·09	E.
Feb. 12	−·034	−·017	−·008	−·020*	−·22	−·15	−·04*	E.

(1ˢ in R.A. = 10″·85 in arc of a great circle.)

The measures made on August 10 are bracketed, as it was found on examination of the images that the dome had cut off a small portion of the object-glass on one side. Half weight has been given to the measures marked * on account of the difference of scale-value which these photographs show.

Using the ten plates from February 28 to May 8 and the five from 1902 January 6 to February 12 we obtain −ˢ·009 for the proper motion in R.A. Similarly the proper motion in declination = −0″·20. Owing to the difficulties arising from the size of the image of the Nova in the early photographs, these results are only provisional, but they show that the Nova has not a very large proper motion.

The measures of these photographs were undertaken with the view of determining the parallax. The parallactic displacement in R.A. corresponding to a parallax of 0″·1 is approximately −ˢ·009 at the end of February and +ˢ·009 in July and August. The actual displacements found at these times are in the opposite direction. Examination of the above table shows that the parallax of the Nova is probably considerably less than 0″·1.

The positive residuals in April may possibly be due to the low altitude of the star, and it may be noticed that the negative values in August are obtained with the instrument on the W. of the pier, while the rest are on the E. of the pier.

Erratum in Annual Report, 1902.

Page 265. line 8, *for* "temporary computer, Mr. Henderson. The Catalogue for 1840 is," *read* "temporary computer. The Henderson Catalogue for 1840 is."

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXII. MAY 9, 1902. No. 7

Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

Alexander Eugen Conrady, F.R.M.S., 104 Park Street, Camden Town, N.W.;
Henry Tresawna Gerrans, M.A., Worcester College, Oxford; and
Maurice Edmond Gheury, 23 Downshire Hill, Hampstead, N.W.,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Henry Cunliffe Hardman, Ruskin College, Oxford (proposed by Sir R. S. Ball);
Francis Kennedy McClean, 1 Onslow Gardens, South Kensington, S.W. (proposed by Frank McClean); and
Rev. Edwin Albert Phillips, B.A., Lecturer in Mathematics, the Training College, Exeter (proposed by Arthur W. Clayden)

Seventy-two presents were announced as having been received since the last meeting, including amongst others:—

Sir N. Lockyer, Total Eclipse of the Sun, May 28, 1900: Account of Observations, presented by the Solar Physics Committee; 63 Charts of the Photographic Chart of the Heavens, presented by the French Ministry of Public Instruction.

Jacobi's Nome (q) in Astronomical Formulæ with Numerical Tables. By R. T. A. Innes.

The Nome q, introduced by Jacobi, can be used in several astronomical formulæ, chiefly as a convenient means of calculating the values of the complete elliptic integrals. It is defined by the following equations :—

$$q = \epsilon^{-\pi\frac{K_1}{K}}$$

wherein

$$K = \frac{2}{\pi}\int_0^{\frac{\pi}{2}} \frac{d\chi}{\sqrt{1-k^2\sin^2\chi}}; \qquad K_1 = \frac{2}{\pi}\int_0^{\frac{\pi}{2}} \frac{d\chi}{\sqrt{1-k_1^2\sin^2\chi}}$$

and

$$k^2 + k_1^2 = 1.$$

We also have

$$K = 1 + \left(\frac{1}{2}\right)^2 k^2 + \left(\frac{1\cdot 3}{2\cdot 4}\right)^2 k^4 + \left(\frac{1\cdot 3\cdot 5}{2\cdot 4\cdot 6}\right)^2 k^6 + \&c.$$
$$= [1 + 2q + 2q^4 + 2q^9 + 2q^{16} + \&c.]^2$$

From these formulæ we may derive

$$q = \tfrac{1}{16}k^2 + \tfrac{1}{32}k^4 + \tfrac{21}{1024}k^6 + \tfrac{31}{2048}k^8 + \&c. \quad \ldots \quad \ldots \quad (a)$$
$$q^1 = \tfrac{1}{2}\sqrt{k} + 2(\tfrac{1}{2}\sqrt{k})^5 + 15(\tfrac{1}{2}\sqrt{k})^9 + 150(\tfrac{1}{2}\sqrt{k})^{13} + \&c. \quad \ldots \quad (b)$$

Schwarz ("Formeln und Lehrsätze zum Gebrauche der elliptischen Functionen," Art. 40) remarks that the nome q and every power of that quantity of which the exponent is a positive number, may be represented by series proceeding according to powers of k, the coefficients of the different terms of these series are positive numbers, and their sum in each case is equal to unity. Unless k is very small the convergency of the two series (a) and (b) leaves something to be desired.

For practical work the series :—

$$q = \tfrac{1}{2}l + 2(\tfrac{1}{2}l)^5 + 15(\tfrac{1}{2}l)^9 + 150(\tfrac{1}{2}l)^{13} + \&c.$$

where

$$l = \frac{1-\sqrt{k_1}}{1+\sqrt{k_1}},$$

or if $k = \sin\theta$

$$l = \tfrac{1}{2}\frac{\sin^2\frac{\theta}{2}}{(1+\sqrt{\cos\theta})^2}.$$

is very convergent.

As K_1 bears the same relation to k_1 that K does to k, it is

evident that if q is tabulated as a function of θ, it will not be necessary to extend the table beyond 45°.

Let q_1 stand to k_1 as q does to k, then

$$q = \epsilon^{-\pi \frac{K_1}{K}} \qquad \text{and} \qquad q_1 = \epsilon^{-\pi \frac{K}{K_1}}$$

and

$$\log \frac{1}{q} = \pi \frac{K_1}{K} \log \epsilon\ ; \qquad \log \frac{1}{q_1} = \pi \frac{K}{K_1} \log \epsilon$$

whence

$$\log \frac{1}{q} . \log \frac{1}{q_1} = (\pi \log \epsilon)^2$$

or by taking logarithms

$$\log \text{ of } \log \frac{1}{q} + \log \text{ of } \log \frac{1}{q_1} = 0{\cdot}269868368 \ \ldots \quad (c)$$

Several tables of q, $\log q$ and $\log$ of $\log \frac{1}{q}$ have been computed, viz. :—

1840.	Jacobi.	Log q to 5 places from 0° to 90° at intervals of 0°·1. (*Crelle's Journal*, vol. xxvi. p. 93.)
1841.	Loxhay.	Log of log $\frac{1}{q}$ to 12 or 14 places from 0° to 45° at intervals of 0°·1. (In Verhulst's *Fonctions Elliptiques*, Bruxelles.)
1860.	Meissel.	Log q to 8 places from 0° to 90° at intervals of 0°·1. (*Sammlung mathematischer Tafeln* 1, Iserlohn.)
1870.	Bertrand.	Log q to 5 places from 0° to 90° at intervals of 5′, and of log of log $\frac{1}{q}$. (*Calcul Intégral*, Paris.)
1877.	Glaisher.	Of q and log q to 8 places for every degree from 0° to 89°. (*Monthly Notices, R.A.S.*, vol. xxxvii. pp. 372–4.)
1879.	Schömlich.	Log q to 5 places for every degree. (*Vorlesungen der höheren Analysis*, p. 448.)
1898.	Levy.	Log q to 5 places from Bertrand *C.I.* (*Fonctions Elliptiques*, Paris.)
1901.	Hoüel.	Log q to 4 places for every centesimal degree. (*Tables Numériques*, Paris.)

(See also Glaisher, Tables, *Ency. Brit.*)

The defect of those tables of the above which have sufficient decimals * for astronomical purposes is their lack of differences, so that on each occasion the tables are used the interpolation would be a longer work than a computation of the function from one of the above formulæ.

I had therefore commenced a table to every minute of the first 45°, giving q to ten places of decimals, with log q and log of log $\frac{1}{q}$

* I have not seen Meissel's Table.

to eight places. This work was not persevered in for several reasons. For tables of not very frequent use they would occupy considerable space. Interpolations would still require the use of second differences in the most favourable part of the table (near 45°) for $\log q$, whilst for small angles interpolation fails altogether in the cases of $\log q$ and log of $\log \frac{1}{q}$. The slow rate of change of a function

$$\frac{q}{\tan^2 \frac{\theta}{2}}$$

suggested that the tabulation of that quantity would suit all ordinary requirements.

Short specimens of the earlier computed tables are given :—

θ °	′	q	Δ	$\log q$.	Δ	log of $\log \frac{1}{q}$.	Δ
0	0	0·000,0000,000+	53	$\bar{\infty}$		∞	
	1	053	159	$\bar{9}$·7233.3226		0 9178,5552	
	2	212	264	$\bar{8}$·3253,9227		·8850,5619	
	3	476	370	·6775 7482		·8646,5494	
	4	846	476	$\bar{8}$ 9274 5233		·8495,7588	
	5	1,322	582	$\bar{7}$·1212.7241	Too large to be tabulated.	·8375,0811	Too large to be tabulated.
	6	1,904	687	·2796,3497		·8273,9286	
	7	2,591	794	·4135,2863		·8186.5281	
	8	3,385	899	·5295,1262		·8109.3699	
	9	4,284	+1005	·6318,1777		·8040,1548	
	10	5,289		$\bar{7}$·7233.3286		·7977,2910	
		. . . . .					
44	50	0·042,8540,371$_{358960}$		8·6319,9174$_{36363}$		0·1360,8872$_{11545}$	
	51	8899,331$_{359163}$		23,5537	353	59,7327	5
	52	9258,494$_{359369}$		27,1890	343	58,5781	5
	53	9617,863$_{359573}$		30,8233	334	57,4236	6
	54	9977,436$_{359779}$		34.4567	324	56,2690	5
	55	3,0337,215$_{359984}$		38,0981	314	55,1145	5
	56	0697,198$_{360188}$		41,7205	304	53,9600	6
	57	1057,386$_{360394}$		45,3509	295	52,8054	5
	58	1417,780$_{360598}$		48,9804	285	51,6509	5
	59	1778,378$_{360805}$		52,6089$_{36276}$		50,4964$_{11546}$	
43	0	0·043,2139,183		8·6356,2365		0·1349,3418	

The table of $\log \frac{q}{\tan^2 \frac{\theta}{2}}$ which follows was therefore computed.

Vega's 10-place tables (Italian edition) were used, hence the tenth decimal is somewhat doubtful. The calculations were checked by differencing. The higher differences in several parts of the table suggested alterations of a few units in the last decimal place of several of the functions; these alterations were adopted, so that finally the run of the differences was smooth enough. Four orders of differences were then changed into differential coefficients and divided by 1, 2, 6 and 24 respectively. The logarithms of the resulting numbers are given. This makes the use of the table in actual practice exceedingly easy, as simple powers of the decimal portion of any given argument are only wanted. I could not derive a workable formula showing the literal forms of the differential coefficients, so that the numbers given probably lack rigid accuracy. Numerous tests, taking the argument positively and negatively (*e.g.* 23°+6′ and 24°−54′) seldom differed by more than one or two units in the last decimal place. Even so q will be furnished correctly to at least 11 places of decimals, an accuracy more than sufficient for any practical requirements.

Log q was computed from the working formula

$$\log q = \log \frac{l}{2} + 2Mq^4 - 3Mq^8 \qquad (M = 0{\cdot}434\ldots)$$

In this formula the approximate value of q required was taken from Glaisher's table already mentioned. The term $3Mq^8$ amounts to one unit in the 11th place of decimals of log q at 45°. The total correction to the approximate formula

$$\log q = \log \frac{l}{2}$$

is shown in a table at the end of this paper. It is arranged so that to seven places of decimals no interpolation is necessary.

Auxiliary Table for the Computation of log q.

$$f(\theta) = \log\left[\frac{q}{\left((\tan\frac{\theta}{2})^2\right)}\right]$$

θ	$f(\theta)$.	$\log f^{I}(\theta)$.	$\log \frac{1}{2}f^{II}(\theta)$.	$\log \frac{1}{6}f^{III}(\theta)$.	$\log \frac{1}{24}f^{IV}(\theta)$.
0°	9·3979400,087	−∞	−∞	−∞	0·77
1	00,093	1·3979	1·5798	1·3979	·78
2	00,187	2·3032	2·1790	1·7076	·79
3	00,597	2·8325	2·5328	1·8808	·80
4	01,701	3·2087	2·7832	2·0004	·81
5	04,033	3·4998	2·9777	2·1038	·82
6	08,278	3·7380	3·1374	2·1875	·83
7	15,281	3·9397	3·2728	2·2577	·84
8	26,046	4·1147	3·3906	2·3181	·85
9	9·3979441,741	4·2693	3·4947	2·3729	0·86

θ	$f(\theta)$.	$\log f^{I}(\theta)$.	$\log \frac{1}{2}f^{II}(\theta)$.	$\log \frac{1}{6}f^{III}(\theta)$.	$\log \frac{1}{24}f^{IV}(\theta)$.
10°	9·3979463,698	4·40782	3·5884	2·4232	0·87
11	79493,421	4·53340	3·6735	2·4698	·88
12	79532,589	4·64831	3·7516	2·5119	·90
13	79583,061	4·75426	3·8239	2·5527	·91
14	79646,882	4·85264	3·89137	2·5911	·92
15	79726,293	4·944492	3·95453	2·6274	·93
16	79823,733	5·030677	4·01406	2·6618	·95
17	79941,848	5·111897	4·07041	2·6955	0·97
18	80083,503	5·188749	4·12405	2·7284	1·00
19	9·3980251,790	5·261719	4·17522	2·7597	1·02
20	9·3980450,038	5·331227	4·22425	2·7903	1·04
21	0681,826	5·397617	4·27131	2·8209	·06
22	0950,991	5·461199	4·31666	2·8506	·08
23	1261,647	5·522241	4·36048	2·8797	·10
24	1618,196	5·580968	4·40290	2·9090	·12
25	2025,345	5·637588	4·44406	2·9375	·15
26	2488,124	5·692279	4·48411	2·9661	·18
27	3011,906	5·7452029	4·52313	2·9943	·20
28	3602,426	5·7965022	4·56126	3·0224	·23
29	9·3984265,805	5·8463056	4·59852	3·0504	1·26
30	9·3985008,569	5·8947253	4·63502	3·0785	1·28
31	85837,679	5·9418686	4·67087	3·1065	·31
32	86760,563	5·9878312	4·70609	3·1345	·34
33	87785,144	6·0326993	4·74076	3·1626	·38
34	88919,872	6·0765523	4·77493	3·1909	·40
35	90173,764	6·1194634	4·80866	3·2193	·43
36	91556,443	6·1615007	4·84201	3·2473	·46
37	93078,189	6·2027275	4·87501	3·2765	·48
38	94749,979	6·2432005	4·90770	3·3056	·53
39	9·3996583,544	6·2829758	4·94013	3·3349	1·56
40	9·3998591,427	6·3221033	4·972342	3·3642	1·59
41	9·4000787,048	6·3606305	5·004360	3·3939	·63
42	3184,773	6·3986027	5·036233	3·4241	·66
43	5799,995	6·4360634	5·068004	3·4547	·70
44	8649,221	6·4730529	5·099701	3·4856	·74
45	9·4011750,169	6·5096105	5·131346	3·5169	1·79

$$\log \text{ of } \log \frac{1}{q^{1}} = 0{\cdot}2698683,680 - \log \text{ of } \log \frac{1}{q}.$$

To find q we have

$$\log q = \log \tan^2 \frac{\theta + h}{2} + f(\theta) + h f^{I}(\theta) + h^2 \tfrac{1}{2} f^{II}(\theta) + h^3 \tfrac{1}{6} f^{III}(\theta) + h^4 \tfrac{1}{24} f^{IV}(\theta).$$

As an example let us compute $\log q$ for $\theta = 44° 4' 18''{\cdot}31$ (or $44° + {\cdot}071753$ or $45° - {\cdot}928247$).

Table	$44°$ =	9·400,8649,221.	$45°$ =	9·401,1750,169
1st diff.	= +	213,252.	= −	3001,055
2nd „	= +	648.	= +	116,593
3rd „	= +	1.	= −	2,630
4th „	= +	0.	= +	46
		9·400,8863,122.		9·400,8863,123

and $\log \tan^2 \frac{\theta}{2} = 9{\cdot}214,3839$ gives $\log q$ 8·615,2702.

A recent interesting application of the nome to astronomical formulæ has been made by Professor G. W. Hill in the secular perturbations of the planets (*Amer. Journ. Mathem.* vol. xxiii. No. 4, and *Astron. Journ.* No. 511). Professor Hill shows that the secular perturbations depend on two quantities, $\mathfrak{K}$ and $\mathfrak{L}$, which have the following values in the notation of this paper :

$$\left.\begin{aligned} \mathfrak{K} &= \frac{K}{k^2_1} = \frac{1}{k^2_1}(1 + 2q + 2q^4 + \&c.)^2 \\ \mathfrak{L} &= \frac{K - E}{k^2 k^2_1} = \frac{8(q - 4q^4 + 9q^9 - \&c.)}{(Kk_1)^{\frac{1}{2}} k^2} \end{aligned}\right\} \quad \ldots \quad \ldots \quad (A)$$

In these formulæ, if θ $(= \sin^{-1} k)$ is under $45°$, q^9 will not affect the 11th decimal, and may be neglected without appreciable error.

When θ exceeds $45°$, q increases in value, and its 9th power may become sensible. If so, it may be better to avoid going beyond $45°$ by the following device.

From

$$q = \epsilon^{-\pi \frac{K_1}{K}}$$

we have

$$K_1 = K \frac{\log \frac{1}{q}}{\pi \log \epsilon} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (B)$$

and from

$$E_1 K + E K_1 - K K_1 = \frac{2}{\pi}$$

we have

$$K_1 - E_1 = \frac{1}{K}\left(EK_1 - \frac{2}{\pi}\right)$$

$$= \frac{1}{K}\left(EK\frac{\log\frac{1}{q}}{\pi \log \epsilon} - \frac{2}{\pi}\right) \quad \ldots \quad \ldots \quad (B_1)$$

where

$$EK = \frac{1 + 3^2q^2 + 5^2q^6 + \&c.}{1 + q^2 + q^6 + \&c.}$$

$$\left(\log \frac{1}{\pi \log \epsilon} = 9{\cdot}86506582,\ \frac{2}{\pi} = 0{\cdot}63661977\right).$$

To apply the above formulæ to the example given by Professor Hill (*Astron. Journ.* No. 511), we have $\theta = 45^\circ\ 55'\ 41''{\cdot}69$ or $90^\circ - 44^\circ\ 4'\ 18''{\cdot}31$. Log q has already been computed for the latter angle ($44^\circ\ 4'\ 18''{\cdot}31$) and by equation (*c*), or by the formula at the bottom of the table, p. 498, we get log q for $\theta = 8{\cdot}6556778$.

In this case to compute $\mathfrak{K}$ and $\mathfrak{L}$ it would obviously be shorter to use the set of formulæ (A), but to exhibit the use of the alternative formulæ (B and B_1) they are employed.

		log of $\log \frac{1}{q}$	$= 0{\cdot}1413650$
$1 + 2q$	$= 1{\cdot}082470806$	$\log \frac{1}{\pi \log \epsilon}$	$= 9{\cdot}8650658$
$2q^4$	$= \quad\quad 5782$		
$\sqrt{K}$	$= 1{\cdot}082476588$		$0{\cdot}0064308 = (\alpha)$

hence

$\log K$	$= 0{\cdot}0688370$
$1/k^2$	$0{\cdot}3153325$
(α)	$0{\cdot}0064308$
$\log \mathfrak{K}$	$0{\cdot}3906003$

Then

$$EK = \frac{1{\cdot}015303347}{1{\cdot}001700363}$$

$$\frac{EK \log \frac{1}{q}}{\pi \log \epsilon} = 1{\cdot}0287003$$

and finally

$$\log \mathfrak{L} = 0{\cdot}1270542$$

It should be noted that Professor Hill's expression for $\mathfrak{L}$ as given in the *Astron. Journ.* is approximate; but as the error is of the order q^9 it is generally negligible.

Several applications of the nome occur in Gyldén's works; one of these is the subject of Dr. Glaisher's paper in the *Monthly Notices*.

As is well known, the elliptic integrals can be used in computing the $b^{(0)}_i$ coefficients in the development of the perturbative function, thus:

$$b^{(0)}_i = 2\mathrm{K}. \qquad (a = k)$$

$$b^{(1)}_i = \frac{2(\mathrm{K}-\mathrm{E})}{k} = \frac{16(q - 4q^4 + 9q^9 - \&c.)}{\mathrm{K}^i k\, k_1}$$

$$a\frac{db^{(0)}_i}{da} = \frac{2(\mathrm{E} - k_1^2\mathrm{K}}{k_1^2} = \frac{16(q + 4q^4 + 9q^9 + \&c.)}{\mathrm{K}^i k_1^2}$$

With the major planets $\theta = \sin^{-1}a$ only exceeds 45° in the case of *Venus* and the Earth, and then only slightly ($\theta = 46°\ 19'\ 49''{\cdot}04$ after Le Verrier). For the latter angle, q is 0·04616097, so that q^9 is entirely negligible. If the ratio a gave a very large angle for θ, the formulæ already quoted can be adapted so that the computation may be made with a value of q for $90° - \theta$. It is somewhat doubtful if the use of the nome in this connection, except in a few special cases, would be found so useful as the Bruns-Harzer method of mechanical quadratures. (See *Die Säcularen Veränderungen der Bahnen der grossen Planeten*, by Paul Harzer, p. 60, also a paper by the same author in the *Mém. de l'Acad. Imp. de St.-Pétersbourg*, 1886, p. 28).

Applications to Geodetical Astronomy will be found in Halphen, *Fonctions Elliptiques*, vol. ii., and in Hoüel, *Tables Numériques*.

Incidentally the following table of log q and log of log $\frac{1}{q}$ each to 10 places was prepared. Log q is new, but log of log $\frac{1}{q}$ has been taken from Loxhay's table; it is therefore possible that there is a want of rigid correspondence between the two sets of numbers, as the values of log q have not been corrected in their last decimals by differencing.

Table of log q and log of log $\frac{1}{q}$.

θ.	Log q.	Log of log $\frac{1}{q}$	θ.	Log q.	Log of log $\frac{1}{q}$.
°			°		
0	$-\infty$		5	6·6781266244	5213830738
1	5·2796568024	0·6739735756	6	6·8367323424	5001359410
2	5·8817829559	6147092317	7	6·9709136917	4813116479
3	6·2340757853	5758715761	8	7·0872300618	4643061837
4	6·4841077801	5460355533	9	7·1899124762	0·4487198467

θ.	Log q.	Log of log $\frac{1}{q}$.
°		
10	7·2818499344	0·4342734299
11	7·3651031297	4207636216
12	7·4411936923	4080374126
13	7·5112772567	3959765166
14	7·5762522110	3844874259
15	7·6368308344	3734948114
16	7·6935874304	3629369962
17	7·7469918430	3527627640
18	7·7974333790	3429290534
19	7·8452382508	0·3333992574
20	7·8906825461	0·3241419463
21	7·9340020238	3151298923
22	7·9753996364	3063393105
23	8·0150513698	0·2977492718
24	8·0531108519	2893412243
25	8·0897130092	2810986181
26	8·1249770129	2730065964
27	8·1590086662	2650517442
28	8·1919023594	2572218795
29	8·2237426822	0·2495058801
30	8·2546057618	0·2418935379
31	8·2845603835	2343754355
32	8·3136689325	2269428411
33	8·3419881948	2195876184
34	8·3695700358	2123021482
35	8·3964619813	2050792612
36	8·4227077213	1979121773
37	8·4483475420	1907944537
38	8·4734187025	1837199374
39	8·4979557644	0·1766827230
40	8·5219908792	0·1696771141
41	8·5455540438	1626975885
42	8·5686733251	1557387650
43	8·5913750603	1487953733
44	8·6136840351	1418622246
45	8·6356236462	0·1349341840

Table showing Error of the Assumption that $\log q = \log \frac{l}{2}$.

[In units of the 7th place of decimals.]

θ.	$\log q = \log \frac{l}{2}$ +.	θ.	$\log q = \log \frac{l}{2}$ +.
°		°	
0 to 11	0·000	31	1·194
12	·001	31·5	1·366
13	·001	32	1·561
14	·002	32·5	1·781
15	·003	33	2·027
16	·005	33·5	2 306
17	·008	34	2·613
18	·013	34·5	2·960
19	·021	35	3·347
20	·032	35·5	3·780
21	·047	36	4·262
22	·069	36·5	4·800
23	·100	37	5·398
24	·142	37·5	6·063
25	·199	38	6·800
26	·275	38·5	7·618
27	·376	39	8·524
28	·509	39·5	9·527
29	·682	40	10 636
30	0 906		

θ.	$\log q = \log \frac{l}{2} +$.	θ.	$\log q = \log \frac{l}{2} +$.
° ′		°	
40 0	10·636	42 40	18·802
10	11·031	50	19·467
20	11·439	43 0	20·152
30	11·961	10	20·859
40	12·297	20	21·588
50	12·748	30	22·341
41 0	13 214	40	23·119
10	13·695	50	23·921
20	14·192	44 0	24·749
30	14·705	10	25·602
40	15·235	20	26·483
50	15·784	30	27·391
42 0	16·350	40	28·328
... 10	16·934	50	29·294
20	17·537	45 0	30·291
30	18·159		

Reductions of Extra Meridian Observations of Planets.

By P. H. Cowell.

(*Communicated by the Astronomer Royal.*)

The following method of reducing observations of planets with the altazimuth has been brought into use at the Royal Observatory, Greenwich.

From the observation of, let us suppose, the Moon, after correcting for instrumental errors and refraction, we have the data:

(1) At time t_1 the Moon's limb was on the standard azimuth (*e.g.* prime vertical, 45° from meridian, &c.)

(2) At time t_2 the Moon's limb was at zenith distance z, after allowing for refraction.

The method aims at transforming these data into the following:—

(1) At time T the Moon's centre was on the standard azimuth as seen from the Earth's centre.

(2) At the same time T the Moon's centre, as seen from the centre of the Earth, was at an inclination Z to the direction of gravity at Greenwich.

It is clear that when this transformation has been accomplished with argument Z we can obtain the Moon's geocentric polar distance and hour-angle; and, combining the latter with T, the right ascension also.

The quantities to be calculated are $T-t_1$ and $Z-z$; the calculation of these quantities is equivalent to reducing the Moon to a star: that is to say, it corrects for the finite parallax and finite diameter.

The method is perfectly general, and is suitable for any azimuth. The computation has been assisted by forming tables for azimuths 90°, 80°, 70°, 60°, and 45°, which are alone used at Greenwich. A special case is given below as illustration; the reasoning and the formulæ apply to any azimuth, the computing to the particular observation.

Description of Term.	Formula.	Numerical Value.
Approximate azimuth motion in one lunar second	$15 \sin \Delta \cos S$	...
Correction for motion in R.A.	$\frac{601{\cdot}643-579{\cdot}682-\mu_a}{579{\cdot}682}$	+0·00336
Correction for motion in N.P.D.	$-\frac{\sin c \sin A \operatorname{cosec} \Delta}{579{\cdot}682}$	−0·001133
B	...	...
Semidiameter	$+1L, -2L$	...
Figure of Earth term ...	$+0{\cdot}003250 \sin A$	+0·003250
Curvature correction ...	$+\frac{15^2}{2\times 206265} t^2 \cos \Delta \sin c \sin A$	...
A	...	...
$T-t_1$	$\frac{A}{B}\times\frac{601{\cdot}643}{579{\cdot}682}$	...
t_1	...	...
T	...	...
t_2	...	...
$T-t_2$	...	...
Approximate zenithal motion in one sidereal second	$+15 \sin c \sin A \frac{579{\cdot}682}{601{\cdot}643}$	...
Correction for motion in R.A.	$\frac{601{\cdot}643-579{\cdot}682-\mu^a}{579{\cdot}682}$	+0·00336
Correction for motion in N.P.D.	$\frac{\cos S}{601{\cdot}643}$	+0·00125
B'	...	...
Motion in time $T-t_2$ ...	$B'(T-t_2)$	...
Semidiameter	$+UL, -LL$	...
Observed z.d., corrected for refraction	...	...
Approximate correction for parallax	$-p\rho \sin(z+\zeta)$	...
Airy correction	...	...
Z	...	...

For planets other than Moon replace 579·682

1899 April 17^d 11^h 13^m·3. Moon on Prime Vertical, West of Meridian.

c	colatitude		38° 31′ 24″
A	azimuth reckoned from south towards west	+	90°
Δ	north polar distance	=	71° 37′ 35′
S	angle at planet subtended by line joining zenith to pole.		
μ_s	motion in R.A. in 10 solar minutes ...	+	20^s·015
μ_Δ	motion in N.P.D. in 10 solar minutes ...	+	81″·14
p	parallax		54′ 16″·39

Precept.	Term.	Remarks.
...	10·7407	For other planets read "one sidereal second."
× 15 sin Δ cos S	+0·0361	...
× μ_Δ	−0·0919	...
sum	10·6849	
...	+888″·82	...
× p	+ 10·58	Compression $\frac{1}{300}$.
...	+ 0·74	$t = \frac{A}{B}$.
sum	+900·14	...
...	+ 87^s·43	...
...	10 55 27·41	...
...	10 56 54·84	...
...	10 56 44·34	...
...	+10·50	...
...	+9″·001	...
× 15 sin c sin A $\frac{579·682}{601·643}$	+0·030	...
× μ_Δ	+0·101	...
sum	+9·132	...
...	+ 1° 35′·89	...
...	− 14 48·82	...
...	+67 17 40·49	...
...	− 49 57·93	$\zeta = -11′\ 11″·7 \cos A$.
...	− 0·11	$\log \rho = 9·999119$. For Moon only.
sum	66 14 29·52	

by 601·643 and omit the Airy correction.

The method of the reduction is sufficiently explained by the first and second columns of the above specimen computation.

The numbers 601·643 and 579·682 that appear in the second column are the numbers of sidereal and lunar seconds respectively in 10 solar minutes.

The formulæ are easily proved; an investigation of the Airy correction is given below.

For the figure of the Earth a compression $\frac{1}{300}$ is used, and ρ is corrected for the height of the observatory above the sea-level.

The Airy correction is the excess of

$$-\sin^{-1}[\sin p(\rho \sin z + \mu)],$$

the true correction for parallax and semidiameter, over

$$-p\rho \sin z - \sin^{-1}(\mu \sin p),$$

which have been applied under the names of "approximate correction for parallax" and "semidiameter." μ here denotes the ratio of the Moon's diameter to the Earth's equatorial diameter, and must be considered negative for the upper limb. Its numerical value is 0·273. The formula is easily reduced to the form

$$\frac{206265''}{6} \sin^3 p \sin z[0{\cdot}78 - \sin z(\pm{\cdot}82 + \sin z)]$$

for the lower and upper limbs respectively.

On the Accuracy of Photographic Measures: Second Note.

By H. C. Plummer, M.A.

1. Since the appearance of my first note on this subject (*Monthly Notices*, vol. lxi., p. 618), in which I took occasion to examine a recent memoir by M. Lœwy, the discussion has been shared by Mr. A. R. Hinks (*Monthly Notices*, vol. lxii., p. 132). More recently M. Lœwy has published two further memoirs of considerable length (*Conférence Astrographique Internationale, Circulaire No.* 9), in which he has developed his researches in a very elaborate manner. In what follows it will be convenient to denote M. Lœwy's first memoir (*Circulaire No.* 8) and the two later memoirs by L_1, L_2, and L_3 respectively, Mr. Hinks' paper by H_1, and my own by P_1. M. Lœwy's purpose, expressed shortly, has been to construct a formula which shall give a superior limit to the probable error of a coordinate determined photographically under any circumstances. If the validity of such a formula once determined be admitted, it will be possible to deduce from it, as M. Lœwy has done, a number of practical conclusions for guidance in the conduct of actual operations. On

the other hand, it may prove more expedient to examine the practical problems which arise individually and in a more simple and direct manner. The possibility of proceeding in this way constitutes one of the vital advantages of the photographic method as compared with methods more familiar in the past, wherein the observations, once made, could not be reconsidered or repeated.

2. The principal conclusions at which I had arrived were not disputed by Mr. Hinks, who, in a desire to avoid reference to the usual theory of errors, employed a line of argument of which it seems difficult to assess the precise value. It may be pointed out, however, that even if all that involved the language of the ordinary theory of errors had been suppressed in my paper the comparative table of discordances (P_1, p. 624) would suffice to prove the main point in question. But there is one small point, in no way affecting my conclusions, on which Mr. Hinks has expressed himself at variance with me. He says (H_1, p. 136), "I do not therefore find myself in agreement with Mr. Plummer when he says: 'We may follow M. Lœwy in denoting the accidental and systematic errors by E_a and E_s respectively, and the total probable error by E_t, and admit that $E_t^2 = E_a^2 + E_s^2$.' This is indeed in obvious contradiction to his conclusion that there is a striking compensation of errors when the plate is measured in reversed positions. . . ." I believe that this criticism is due simply to a slight misconception of the policy underlying my paper. In § 5 (P_1), where the words quoted by Mr. Hinks occur, I was following M. Lœwy's views as closely as possible. There was no proof at that stage that M. Lœwy was essentially wrong. Afterwards, in its logical place, the application of the law is denied in sufficiently clear terms. Thus in § 11 (P_1, p. 625) ". . . in general it" (*i.e.* the error removed by reversing the plate) "will not obey the axioms on which the ordinary theory of errors is founded," and again in § 12 (P_1, p. 626): "Evidently we must regard as the unit of measurement, *not* a measure made in a single orientation, *but* the mean of two effected on the plate in the direct and reversed position." These statements sufficiently cover § 5 and remove my responsibility for any preliminary statement made there.

3. But though this explains the point raised by Mr. Hinks, and shows that we are really in agreement, the point may usefully be considered further, and its examination will serve as an introduction to the remarks to be made on M. Lœwy's papers. If we have an error t which must be considered as made up of two parts a and s, so that $t = a + s$, then

$$t^2 = a^2 + 2as + s^2.$$

It follows that if mean values are taken of both sides of the equation, in a purely statistical sense and with an obvious notation,

$$\epsilon_t^2 = \epsilon_a^2 + \epsilon_s^2$$

provided that (1) a and s are really independent, and (2) positive and negative values of a are equally likely to the same amount. The formula does hold then in a certain sense for errors of mean square. But if we deduce a corresponding formula for probable errors on the supposition that the probable error bears a fixed ratio to the error of mean square, the result will be not merely wrong but unmeaning, unless both the errors a and s obey certain laws too well known to make it necessary to specify them here. And even if we *define* a probable error as bearing the ratio to the error of mean square of ·6745 : 1, which would be consistent with the ordinary theory, it would still remain true that the resulting formula would have no useful meaning, and no useful deduction whatever could be derived from it. Similarly it is easy to assume a more extended formula, such as

$$\epsilon_i^2 = \frac{\epsilon_1^2}{m_1} + \frac{\epsilon_2^2}{m_2} + \frac{\epsilon_3^2}{m_3} + \ldots$$

when a number of sources of error are in question, and there is no formal difficulty in deriving a set of constants from a sufficient number of equations which are to be obtained by varying the conditions of observation. But, again, it is quite obvious that the result can bear no useful meaning unless we are prepared to subscribe to certain articles of belief as to the nature of the sources of error involved. And there is a further difficulty in practice. The probable errors in the several cases can be determined easily enough, but we can seldom ascribe to them a high degree of precision, and that for several reasons, such as the finite number of the residuals on which they are based. Consequently the more complicated the formula assumed the more will errors accumulate in the determination of the constants, until from this cause alone an absolutely fallacious result will be obtained.

4. The principles here laid down will probably not be disputed : on the contrary, they are more likely to be considered too obvious to need expression. But they are precisely those which the method of M. Lœwy's first memoir disregarded ; and in his later work the same faulty method is pushed to what appear to me extravagant lengths. Whenever a discrepancy arises in the application of the formula it is fatally easy to assume a fresh source of error and to add a term ϵ_r^2 multiplied by some arbitrary numerical factor. But it is difficult to be assured that the final formula is really in accordance with the laws of probability, or that it is not vitiated by a mass of accumulated error. In the absence of such assurance the results cannot command our confidence. M. Lœwy has assumed the possibility of constructing a formula which shall include all possible sources of error and meet all cases. To speak shortly, I am not prepared to admit that possibility. A too complicated formula of the kind in question seems to me to fall of its own weight.

5. My previous paper was confined to a consideration of the accuracy of the measures of photographic images, and was not concerned with the accuracy of the positions of the images themselves. Although M. Lœwy's later work is devoted to the investigation of the precision of measured coordinates in the wider sense, and to the examination of a number of important questions, I do not intend to enlarge the area of discussion. Mr. Hinks seems to go rather too far when he says (H_1, p. 137): "It is, then, of no consequence to examine elaborately the divergences from the mean of settings on a single exposure." Undoubtedly this is only a question of a preliminary character, and its solution will not carry us very far. But it is none the less an important one, and appears fundamental in M. Lœwy's method of inquiry. To put the matter as briefly as possible, the main practical conclusion of my former paper was that no essential advantage is to be gained by measuring the position of a single image in more than two orientations of the plate, and that opposite orientations (*e.g.* 0° and 180°) should be chosen. This contention was opposed to M. Lœwy's view that measures in four orientations were necessary, and was based partly on the fact that M. Lœwy's general formula did not apply to measures made in opposite orientations. From this it appeared that *one class of error* was eliminated by reversing the plate. In an Avant-propos, in which he has done me the honour to make reference (but in no sense a reply) to my criticism, M. Lœwy attributes to me the belief that "il suffit, pour tenir compte des erreurs systématiques et pour les éliminer, de faire des mesures dans deux positions de la plaque différentes de 180°." This rather overstates my view, for I said distinctly (P_1, p. 626): "I do not mean to say that the whole error, apart from what is purely accidental, can be removed by simply reversing the plate."

6. Before I leave the Avant-propos, another passage may be mentioned which seems to indicate a misapprehension in M. Lœwy's mind. Referring to his third memoir, he says: "Cette troisième recherche . . . a . . . révélé ainsi l'existence d'une nouvelle source d'erreur. Contrairement au reproche d'avoir attribué, d'après mes formules, des erreurs probables trop fortes aux résultats, il est arrivé ce qui était à redouter, que cette précision a été surestimée. Cette dernière source d'erreur provient de la déformation de la gélatine. . . . Il résulte de ce fait une inexactitude accidentelle . . . indépendante d'ailleurs de toutes les opérations de mesure." I may be wrong in supposing that this passage is suggested by my "reproche," though the context seems to support that view. But if I am not, it suggests that possibly some slight confusion of ideas may be involved. Clearly it is no answer to the question how accurate are the measures to say that inexactitudes exist which are independent of the process of measurement. As a matter of fact the passage quoted does not apply to my paper at all. My third conclusion (P_1, p. 628) was: "If M. Lœwy's estimate of the precision

of measures so made be accepted, it does not follow that it is worth while to repeat the measures as many times as he thinks necessary." The grounds on which this opinion was based are set out in § 9 (P_1, p. 623), in which the reason assigned is precisely the "systematic error," *i.e.* "l'inexactitude indépendante de toutes les opérations de mesure."

7. At the beginning of his second memoir M. Lœwy distinguishes two parts in the total error of a measure, the accidental and the systematic, and subdivides the latter into (1) ϵ_{s_1} the error which he calls "l'erreur permanente physiologique," and (2) ϵ_{s_2}, the error which "provient d'une appréciation erronée du centre du disque." He seems to consider ϵ_{s_1} to be of a magnitude too small to enter into the account, an opinion of which something will be said in § 12. With regard to ϵ_{s_2} he says (L_2, p. 11): "je considère les deux valeurs de ϵ_{s_2} comme étant complètement indépendantes l'une de l'autre aussi bien en signe qu'en grandeur, la personnalité de l'observateur disparaissant ici complètement." In a case when rapid reversal is possible, he admits, however, that "il peut se produire certaines compensations avantageuses d'une partie des erreurs systématiques ϵ_{s_1}, si toutefois celles-ci existent." Might it not be suggested that a practical inference, such as that instrumental means ought to be provided for making a rapid reversal possible if the best result is to be obtained, is perhaps of greater value than an elaborate formula based on the principle "qu'il vaut mieux toujours attribuer aux sources d'erreurs leur maximum d'effet."

8. It appears that the second memoir was practically completed before my criticism of the first was published. It is rather hard to say whether the error removed by reversing the plate belongs to the category ϵ_{s_1} or ϵ_{s_2}, but that matters little. What I hold to be beyond dispute is that in the case of the plate designated P by M. Lœwy, a class of error did exist which did not possess the quality of mutual independence, and that his formula broke down when applied in a particular instance. Is it, then, to be supposed that that formula can safely be applied to any plate *except* the very one on which it is based? And this objection is by no means met by M. Lœwy's contentions that the compensations are due to chance. In the case of a series of measures of abscissæ (L_2, p. 77) he obtains a better compensation between certain columns of residuals by making a certain artificial arrangement. It might be suggested that this effect is not wholly unconnected with the fact that the list contains only 21 stars, and these are selected "belles images" within a restricted range of magnitude. But as regards the marked compensations proved in my former paper, I cannot help thinking that M. Lœwy's attempt to attribute them to chance is by no means favourable to his own case. If the disturbing effects of chance are so serious in one case they are likely to be as great in

others, and the numbers which he has deduced from the plate P must all lie under the same suspicion. If the argument be admitted, the weight to be attached to the results of the first two memoirs is small indeed.

9. It may be remarked at this point that M. Lœwy in his first two memoirs has sought to erect a vast edifice on a singularly slender foundation—in fact, on a single plate, if I have not misunderstood him. It is useless in a matter of this kind to seek support in vague appeals to "experience." On the other hand the strength of the critical position depends on the fact that the objections which have been raised have been based on M. Lœwy's own material. Now, as to these observations, some comments must be made. M. Lœwy remarks (L_2, p. 11): "En ce qui concerne le cliché P, quelques incertitudes très légères se sont révélées au début des mesures, où les observateurs A et B n'avaient pas la sûreté d'une pratique prolongée, mais ultérieurement, pour tous les deux, l'erreur ϵ_{s_1} s'est complètement évanouie." It is unfortunate that a research which pretends to a fundamental character should have been based on the work of inexperienced measurers. Another remark of M. Lœwy's is also noteworthy (L_2, p. 47): "Je dois à cette occasion faire remarquer que l'observateur B se trouvant absent pendant plusieurs jours, quelques-unes des mesures, huit ou dix séries, ont été effectuées par l'observateur A, substitution qui . . . ne donne lieu à aucun inconvénient." This is also unfortunate, and reveals the gratuitous nature of M. Lœwy's assumption that a change of orientation with a single observer is equivalent to a change of observers. It may also help to explain the notable discontinuities which I found in my former paper (P_1, § 7)—and Mr. Hinks confirms me—to exist in the residuals of B in certain orientations. But the fact that measures actually made by A were in effect labelled as those of B stands in no need of comment.

10. One very considerable concession M. Lœwy has made. He has not only given a general formula for the probable error according to his own ideas and assumptions, but he has also given a second solution of the problem which is based on the means of measures effected in opposite orientations of the plate. He admits (L_2, p. 57) that "cette formule aboutit pour ϵ_i^m" (the probable error) "à des valeurs inférieures à celles que donnerait la formule (C)." But he contests its validity on two grounds: "Non seulement la seconde solution ne peut être appliquée aux opérations de mesure exécutées dans une seule orientation, mais elle donne un résultat trop faible et trop éloigné de la vérité." The latter reason is a mere statement and nothing more. The former objection is irrelevant, for my whole point is that the mean of measures in opposite orientations is to be regarded as the unit of measurement. I do not admit the possibility in general of constructing a single formula which shall represent the accuracy of single measures and those made in

properly chosen orientations, because there is no continuity between the two cases And therefore, when M. Lœwy manipulates his second solution by the addition of numerous terms, there can be no agreement with his method of procedure, nor can the results be accepted of which he says (L_2, p. 59): "Le système de formules (G) ainsi amélioré devient maintenant applicable à tous les cas, même pour les mesures faites dans une seule orientation de la plaque." This contradicts the very hypothesis (be it right or wrong) on which the formulæ are based, and the results need not be discussed further.

11. Certain points in M. Lœwy's third memoir may now be briefly considered. His object here is to compare the measured coordinates with those deduced from the meridian observations of *étoiles de repère*, and the material for discussion is provided by measures effected on an *Eros* plate designated BI. It is not intended to go beyond the limits imposed in § 5, except to notice one point which presents itself at the end of the memoir. M. Lœwy finds that the probable discordance between abscissæ is $0''{\cdot}167$ when determined by direct comparison and $0''{\cdot}129$ when calculated *a priori* from his formula. He claims that (L_3, p. 115) "la divergence . . . n'est pas en vérité notable." Now, clearly it might be caused by a systematic error, which has been overlooked, of probable magnitude $0''{\cdot}10$. There is no need to lay any great stress on the discrepancy, which might be accounted for in several ways; though M. Lœwy seems quite inconsistent here when his previous treatment of minute differences is borne in mind. But surely he is not justified in saying: "L'accord entre les erreurs prévues et celles qui se manifestent réellement semble apporter une démonstration décisive de la rigueur des formules destinées à l'évaluation de l'erreur probable des coordonnées rectilignes tirées des clichés." This expression of unqualified satisfaction does seem somewhat out of place.

12. There is only one other passage in the third memoir which will receive criticism, but that serious criticism. M. Lœwy gives at full length tables which contain the ordinates measured in four orientations by A and B, the differences between the means for the two observers, and the mean of the eight ordinates for each star. It is pleasant to be able to acknowledge gratefully the ample and clear form in which M. Lœwy gives his material. With regard to these tables he says (L_3, p. 88): "A l'aide de ces éléments on peut aisément se convaincre que non seulement les ordonnées trouvées par les deux observateurs sont absolument identiques (abstraction faite des erreurs accidentelles), mais encore que l'erreur physiologique ε_{a_1} n'existe pas ou n'a pas de valeur appréciable ni pour l'observateur A ni pour l'observateur B." Comment on the first remark is reserved for 14. The truth or otherwise of the second statement may be gathered from an inspection of the Table of

Personality which I have constructed by subtracting from each measure the mean for each observer, and adding the results for each orientation and dividing the sums by 43, the number of the stars. The numbers in the first column are those of the sections of Tableau III., corresponding to the six images whose ordinates were measured.

Table of Personality.

Tableau III.	A				B			
	0°.	180°.	90°.	270°.	0°.	180°.	90°.	270°.
	"	"	"	"	"	"	"	"
2	+0·092	−0·102	+0·053	−0·042	+0·070	−0·037	+0·029	−0·062
3	+ ·096	− ·117	+ ·077	− ·056	+ ·076	− ·044	+ ·020	− ·050
4	+ ·070	− ·103	+ ·073	− ·038	+ ·059	− ·019	+ ·032	− ·071
5	+ ·092	− ·095	+ ·071	− ·066	+ ·086	− ·055	+ ·050	− ·081
6	+ ·113	− ·112	+ ·083	− ·085	+ ·075	− ·046	+ ·038	− ·068
7	+ ·114	− ·120	+ ·076	− ·069	+ ·075	- ·051	+ ·038	− ·064
Means =	+ ·096	− ·108	+ ·072	− ·059	+ ·073	− ·042	+ ·035	− ·066

In the face of these figures can M. Lœwy's denial of the existence of the "erreur physiologique" be maintained? But perhaps he will say they are small. "Valeur appréciable" is a relative term, it is true. But there is an answer to this objection which seems to me final. *The magnitudes of these constant errors are in many cases sufficient practically to control the signs of the residuals.* Thus for the observer A's measures in orientation 0° *only* 40 *residuals are negative in a total of* 258! Surely so great an "écart" ought to be attributed to a cause.

13. The task of discussing a set of residuals is always a delicate one, and M. Lœwy has not avoided a serious error. The true principle was expressed admirably by Gauss, and in this matter we have not advanced beyond his position when he wrote: "Scilicet observatoris est, omnes caussas, quæ errores constantes producere valent, sedulo investigare, et vel amovere, vel saltem eąrum rationem et magnitudinem summo studio perscrutari, ut effectus in quavis observatione determinata assignari, adeoque hæc ab illo liberari possit, quo pacto res eodem redit, ac si error omnino non affuisset." In addition to eliminating the personal equation, there seems to be, contrary to what might have been expected, little extra advantage in the case of these measures in combining opposite orientations. But that is not really surprising. M. Lœwy has detected more pronounced errors in the measures of the fainter stars, and these have been omitted, so that we are dealing only with a limited range of magnitude. The images possess a more homogeneous character, and the measures are naturally of a higher order of accuracy. The "systematic error" with which M. Lœwy alarmed us must be very small, and further compensations cannot be expected when the errors are almost purely accidental. In practice constant per-

sonal equation matters little, for it disappears of course in the process of finding the plate constants. It amounts merely to a virtual displacement of the réseau. But it has one inconvenience. If a doubt arises as to the correctness of the measures of an individual star, it is impossible afterwards to revise the measures with any certainty unless the personality of the original measurer was determined at the time. For instance, this impossibility applies to the whole of the astrophotographic plates measured at the Paris Observatory. I regard some of the smaller numbers in the preceding table as due, not to the absence, but to the variability of the personal equation. The residuals in some cases seem to suggest this idea very strongly.

14. I have already remarked that M. Lœwy's statement that a change of orientation with a single observer is equivalent to a change of observer is simply an unproved assumption. It is interesting, therefore, to examine the differences between the means of measures by A and B of the ordinates of six images of forty-three stars. Now such differences are equally likely to be of either sign, and the chances of 6, 5, 4, 3 like signs are as 1 : 6 : 15 : 10. As a matter of fact, the numbers of sets of differences with the stated numbers of like signs are 7, 11, 11, 14 respectively, where we should expect about 1 or 2, 8, 20, and 13. The numbers are too small to lay any stress upon them. But the number of sets of differences without a change of sign seems rather larger than it ought to be. Accordingly these cases seem to be worthy of being reproduced in detail, an extra star being given which is not strictly qualified to appear. The unit of the differences is 0″·0001, and the numbers at the bottom may be regarded either as sums with this unit or as means with the unit 0″·001.

Star No.	9	15	17	27	29	36	38	25
Image 1	+ 3	+ 64	− 12	− 9	+ 12	+ 4	− 6	− 30
2	+ 1	+ 57	− 4	− 3	+ 2	+ 12	− 19	− 20
3	+ 2	+ 61	− 10	− 5	+ 80	+ 7	− 7	− 37
4	+ 14	+ 3	− 15	− 32	+ 23	+ 7	− 8	− 19
5	+ 13	+ 45	− 25	− 27	+ 7	+ 4	− 11	− 7
6	+ 8	+ 21	− 26	− 27	+ 11	+ 6	− 14	+ 4
	+041	+251	−092	−103	+135	+040	−065	−109

Now the stars 9, 36, and 38 can be dismissed from consideration as satisfactorily measured. But can the same be said of the others? Each observer has effected his measures in four orientations on six several images. Is it right that in four cases (roughly 10 per cent.) a discordance of practically 0″·1 or more should appear between the means, while in a fifth case the discordance actually amounts to a quarter of a second of arc? The odds against such a case as is presented by star 15 must be something like 10,000 to 1, if chance alone is in operation. Of

course it is possible that M. Lœwy has been unfortunate, and has included among his forty-three stars a case which will only recur once in, say, 10,000 times. If that be so, it is singularly unfortunate that all the observations of this star were not most carefully re-examined. It is curious that M. Lœwy nowhere mentions that immense advantage of the photographic over more direct methods, the possibility of easily referring again to the plate in cases of doubt and revising the measures with special care. But here I cannot think that we have to do with a mere play of chance. It does seem that the observers A and B do systematically differ in their estimation of the centre of the star, and as the difference does not appear merely in the measures of a single image a real cause must perhaps be sought in the nature of the star! This will no doubt appear fanciful,* but it cannot be denied that we have here a singular and apparently inexplicable cause for disquietude. At any rate, it seems clear that the method of multiplied orientations is *not* effective in all cases, though it may be so in the case of the majority of images. If exceptional cases be admitted, we have another reason for saying that no general formula can be constructed for the probable error of a measured coordinate.

15. In conclusion, although M. Lœwy has raised a number of interesting and important questions and has made suggestive contributions towards their solution, the questions have probably not received their final answer, and there seems to be still ample scope for further inquiry. The grounds on which this opinion is based may now be summarised thus:

(*a*) The general method adopted by M. Lœwy is open to objection for two reasons: (1) It is based on assumptions as to the nature of the errors involved the soundness of which is certainly doubtful; (2) the results may be vitiated in a great measure by an unavoidable accumulation of arithmetical error (§§ 3, 4).

(*b*) The observational material discussed is not without defects: (1) It is too restricted in quantity and derived from too small a number of plates; (2) some of the measures were made by inexperienced observers; (3) insufficient care was taken to keep the results of different measurers distinct (§ 9).

(*c*) The contention that personality has no appreciable value cannot in general be maintained. The effect of this equation is proved to be in some cases pronounced (§ 12).

(*d*) The method of changing the orientations in which measures are effected may serve its purpose in reducing the systematic error of measurement in the majority of cases. But it is at least possible that exceptional cases may occur in which the multiplication of orientations will fail to reconcile estimations of the centre of an image on the part of different observers.

* Perhaps a more reasonable cause of the systematic discrepancy may be found in local irregularities in the character of the réseau lines.

An instance is quoted in which such a discrepancy persists even for different images of the same star (§ 14).

University Observatory, Oxford:
1902 *May* 7.

Visual and Spectroscopic Observations of the Sun-spot group of 1901 *May* 19–*June* 26. By the Rev. A. L. Cortie, S.J., F.R.A.S.

The group of Sun-spots of 1901 May 19–June 26, seen during two solar rotations, is noteworthy for several reasons. First, it was a large group visible to the unaided eye, occurring at a time of Sun-spot minimum. If one group of small spots seen between March 3–11 be excepted, the solar surface had been quiescent for almost exactly six months before the appearance of this group, without any spots and with very few faculæ, and these faculæ more than ordinarily faint. The following table deduced from the Stonyhurst series of Sun-spot drawings, supplemented by a very full series of direct visual observations by Mr. Hadden, of Alta, Iowa, U.S.A., shows the quiet state of the solar surface between 1900 November and 1901 April before the advent of the big group of May–June. The greatest visible disc-area of the group from the Stonyhurst drawings was 7·6 on May 22, the unit being $\frac{1}{5000}$ of the visible disc. In the former Sun-spot minimum of 1889 a big spot also appeared, that of June, as a contrast to the general quiescence. The recurrence of the phenomenon during the present minimum, even if only a coincidence, is noteworthy.

Month.	Days of Observation.	Mean Daily Spots.	Number of Groups. Faculæ.
1900 November	26	0·42	0·62
December	29	0·10	0·59
1901 January	28	0·00	0·18
February	26	0·31	0 58
March	30	0·53	0·63
April	30	0·00	0·70
May	31	0·61	1·09
June	30	0·73	0·73

1. A unique interest attaches to the 1901 outburst in that, as Mr. Perrine and the Greenwich observers have shown, it was very close in position when just out of sight beyond the E. limb on May 18, to a fine prominence, and, what is still more remarkable, to a disturbed area of the solar corona observed during the total

solar eclipse of that date. In a previous short account of this Sun-spot group communicated to the *Observatory* (No. 306, June 1901), and before any knowledge of the coincidence in position of the Sun-spot, prominence, and coronal disturbance was attainable, it was stated that "the group was born very close to the E. limb on the invisible side of the Sun, being probably two or three days old when first observed at Stonyhurst on May 20th." In the paper, "On the Types of Sun-spot Disturbances" (*Astrophysical Journal*, vol. xiii. No. 4, May 1901), it is shown how it is possible from the type of a Sun-spot to give a very fair estimate of its age and the date of its birth, even if, as in the present case, it was born on the invisible side of the Sun. It is then most likely—in fact almost certain—that the disturbance in the corona was not only coincident in position with the Sun-spot, but in time also with the date of its birth, and that we witnessed in the corona the effects of the solar disturbance accompanying the birth of the spot.

2. Premonitory signs of this, the only great outburst of the year, had been given for about a month previously to its appearance. On the drawings of April 15, 16, 17, the observer notes that regions north of the equator were disturbed as indicated by the appearance of many groups of evanescent veiled spots. On the 20th the Sun's surface displayed most active and continual changes in the appearance and disappearance of veiled spots. It is to be noted, too, from the table given above that the mean daily number of faculæ gradually increases from January to April, even though they were faint and not very extensive. On April 21 a bright patch of faculæ was both noted by Mr. Hadden and drawn by the Stonyhurst observer on the Sun's E. limb. Its character of brilliancy and compactness was such as accompanies the first appearance of Sun-spots, though on the three following days it was followed by other less brilliant faculæ of more extended area. There is a bare possibility of these faculæ indicating the region of a short-lived spot group that ran its course on the invisible side of the Sun. But the position of the bright patch of April 21 was longitude 168° and N. latitude 8°·5. This is the very position of the spot which subsequently appeared on May 19 at the next rotation, a difference of 8° in longitude between the centre of the faculous and spot groups being accounted for by the extent of the faculæ, and by the difficulty of making extremely accurate measurements when objects are close to the Sun's limb. The coordinates of the spot group on May 20 were longitude 160° and N. latitude 9°. We have here another instance of a facula preceding a Sun-spot to be added to the seven clear cases found on the Stonyhurst drawings, but in this case what is remarkable is that it precedes it by a whole solar rotation. If the barely possible surmise of the faculæ of April 21 and following days, being the remnants of a short-lived storm which had occurred on the invisible hemisphere of the Sun, be admitted, then at least we have a good instance of one spot following another in almost

the same position, and thus giving rise to a disturbed area, observed also in the solar corona of May 18.

3. During the first appearance the spot was visible from May 19 to May 31, attaining its greatest area on May 22. From May 13 to May 22 the magnets were absolutely quiet; from May 22 to May 29 there was a series of small disturbances. May 30 was a quiet day, followed by a small disturbance on May 31, so that during its first passage across the visible disc, when the spot displayed great activity and attained its maximum area, the magnets did not show even a moderate disturbance. In June the spot was visible for a second time from the 14th to the 26th, when it was much reduced in size, being almost extinct when it reached the W. limb on June 26. There were two moderate disturbances of the magnets on the 13th and 21st, the only two during the month. The other days were days of calm or but slight disturbance. As a set off there were also two moderate disturbances in July when the Sun's surface was almost absolutely quiescent. The one great solar disturbance of the year, therefore, which showed itself in a spot visible to the naked eye, in a fine prominence, in bright faculæ, and in a unique coronal disturbance, was unaccompanied by any considerable magnetic storm, and seemingly had but a fortuitous connection with the slight and moderate disturbances which occurred during its existence.

4. The spectrum of the spot was first observed on May 22 between 2 and 3·30 P.M., G.M.T., when the seeing was excellent. The Browning automatic spectroscope attached to the Perry Memorial 15-inch telescope was used for the observation, the full battery of 12 prisms of 60° being employed. Before the detailed examination of the portions of the spectrum contained in the following table was made, the whole of the lines between C and D were carefully passed in review several times. The lines usually observed as most widened were unchanged, the most widened lines being faint lines chiefly due to vanadium. The general absorption was only moderately dark.

Wave-length.	Element.	Widening.	Intensity.	Remarks.
6039·9	V	1·0	0	Most widened line.
6053·9	Ni	1·0	0	„ „ „
6063·1	...	1·0	0	„ „ „ Observed May 2
6243·1	V	1·0	000	„ „ „
6252·8	...	0·5	7	V line at 6252·0.
6254·4	Fe	0·5	1	
6254·5			5	
6256·6	Ni–Fe	0·5	6	
6258·3	Ti	0·8	2	
6258·6	V		000	

Wave-length.	Element.	Widening.	Intensity.	Remarks.
6261·3	Ti	1·0	1	A V line very near.
6265·3	Fe	0·4	5	
6267·0	...	1·0	0000	A V line at 6269·0.
6274·8	...	1·0	00	A line just before head of α band, always very widened.
6282·9	Co	0·5	2	
6291·2	Fe	0·5	4	
6293·0	V	0·5	000	
6296·2	A(O)	0·5	3	Widening perhaps due to a V line at 6296·6.
6306·0	O	1·0	2	Some other lines in the α band were somewhat widened or darkened, but this pair was quite conspicuous, especially the more refrangible line.
6307·0	O	1·0	2	
6311·7	Fe	0·5	1	
6322·9	Fe	0·5	4	
6330·3	Cr	0·5	1	A Fe line very close.
6344·4	Fe	0·5	4	
6355·2	Fe	0·5	4	
6358·9	Fe	0·5	6	
6393·8	Fe	0·5	7	A close double.
6400·2	Fe	0·5	8	,, ,, ,,
6405·9	...	0·8	00	
6408·2	Fe	0·5	5	
6411·8	Fe	0·5	7	
6415·2	...	...	1	Obliterated over spot.
6417·1	Fe?	...	1	,, ,, ,,
6420·2	Fe	0·5	4	
6421·6	Fe	0·5	7	
6431·1	Fe	0·3	5	
6432·9	Fe?	0·8	1	
6436·6	Fe?	0·8	0	
6439·3	Ca	0·5	8	
6450·0	Ca	0 5	6	
6455·8	Ca	0·8	2	
6456·6	...	0	3	
6462·8	Ca	0·5	5	
6463·0	Fe		3	
6469·4	...	0·5	2	Also darkened in spot.
6471·9	Ca	0·5	5	,, ,, ,,
6475·8	...	0·8	2	,, ,, ,,
6494·0	Ca	0·5	6	

Wave-length.	Element.	Widening.	Intensity.	Remarks.
6495·2	Fe	0·5	8	
6499·9	Ca	0·8	4	
6546·5	Ti–Fe	0·4	6	
6563·0	Hα	0	40	

The identification of the lines during the observations was made by means of Higgs's Photographic Atlas of the Normal Solar Spectrum. The wave-lengths, elements, and intensities are taken from Rowland's Preliminary Table of Solar Spectrum Wave-lengths. The widening of the lines is estimated as far as possible in terms of the normal width of the line. The observations of May 22 were revised on May 23 and 24, employing the 1st and 2nd orders of a Rutherfurd grating. The same lines were affected. The most widened line between D and *b* seemed to be 5210·6, due to titanium.

The following table gives a comparison between the average widening and average intensity of the lines of the various elements observed. In Rowland's table the intensities of the lines are reckoned from 1, a line just clearly visible on the map, to 1000 for H and K. Faint lines below intensity 1 are reckoned in order of faintness from 0 to 0000. In taking an average of the intensities of the lines of any one element observed, 0 to 0000 for the sake of comparison have been reckoned as −1 to −4.

Element.	Number of Lines observed.	Mean Widening.	Mean Intensity.
Iron	19	0·5	+ 5·2
Calcium	7	0·6	+ 5·7
Titanium	3	0·7	+ 3·0
Vanadium	4	0·8	− 2·5
Nickel	2	0·8	+ 2·5
Cobalt	1	0·5	+ 2·0
Chromium	1	0·5	+ 1·0
Oxygen?	2	1·0	+ 2·0
Hydrogen	1	0·0	+40·0
Unknown	8	0·7	+ 0·6

Excluding the lines of unknown origin, the two doubtful lines of oxygen, and the single lines of cobalt and chromium, the mean widening is almost inversely as the mean intensity. This fact again corroborates the statement made in several previous papers (*e.g. Monthly Notices, R.A.S.* vol. xlix. No. 8, June 1889, p. 417), that at least in this portion of the spectrum the most widened lines in Sun-spots are at all periods of solar activity faint lines due principally to vanadium. In the case of iron and titanium we find in the spot-spectra the same relation between

widening and average intensity as is found by Mr. Evershed (*Memoirs R.A.S.* Appendix II. vol. liv. 1901, p. [91]) between intensity in the "flash" spectrum and intensity in the solar spectrum. Vanadium and titanium are also elements the lines of which are strong in the flash but comparatively weak in the solar spectrum, and the lines of these elements are also, as has been stated before (*Monthly Notices, R.A.S.* vol. li. No. 2, December 1890, p. 77, and vol. lviii. No. 7, May 1898), very much widened in all spots whether of the maximum or minimum epoch. It would seem to follow that the level of Sun-spots is the level of the upper more extensively diffused portion of the stratum of gas which gives the flash spectrum in eclipses. The following is a summary of the chief results which follow from the detailed study of this Sun-spot group :—

1. That the disturbed area of the solar corona of 1901 May 18 marked the time of the actual outburst of the spots.

2. The outburst occurred in a region which had been disturbed for at least a whole rotation of the Sun before the birth of the spots.

3. That in this case of the only great Sun-spot of an otherwise absolutely quiet year there is no connection between the solar storm and magnetic disturbances.

4. That the most widened lines in the spectra of Sun-spots in the red end of the spectrum are always faint lines, chiefly due to vanadium and titanium.

5. That the level of Sun-spots is the level of the upper more diffused gases which give the flash spectrum in total eclipses.

Stonyhurst College Observatory :
1902 *May* 4.

The Spectrum of Nova Persei 1901 *on and after September* 5.

By the Rev. Walter Sidgreaves, S.J.

A reproduction of the spectrum of the Nova, as photographed at Stonyhurst on August 27 and September 5, is given at p. 150 of the December number of the *Monthly Notices*. Since then forty-one photographs have been taken on twenty-eight nights, distributed as in the following list; in which the letters written after the dates have the same significations as in the wave-length tables of the paper referred to : viz. H the Hilger compound prism on the Perry-memorial Equatorial, and T the Thorp objective prism on the 4-inch finder :

September 6, H ; 11, T ; 14, H, T ; 15, H, T ; 24, H.
October 4, H, T ; 6, H, T ; 18, H ; 19, H, T ; 31, T.
November 1, H ; 2, T ; 14, T ; 22, H, T ; 23, H, T ; 28, H, T.
December 5, T ; 14, H, T ; 18, T ; 20, H, T.

January 14, H; 15, H, T; 28, H; 29, T; 30, H, T; 31, H, T.

February 10, H; 12, H.

All these plates show the same spectrum in its general features; the lines remain very broad, and preserve their relative intensities. This stability of the spectrum is shown in Table I.; in which the figures of the first column are brought forward from the December paper for comparison with those of the later dates. The measured widths of the lines are given under the letter w; but the relative intensities have been omitted on account of the discrepancy between the relations as shown by the two spectroscopes employed for the complete spectrum.

In the fourth column, for February 10 and 12, the widths of three lines only are quoted. These could be measured without difficulty, but the edges of the rest were found to be too ill-defined. The star was very small, and the trail across the plate was necessarily too slow for satisfactory definition.

TABLE I.

Bright line spectrum of Nova Persei, 1901.

Oct. 4 & 6.		Nov. 22.		Dec. 20.		Feb. 10 & 12.	
λ	w	λ	w	λ	w	λ	w
386·8	2·5	386·8	3·2	386·8	2·6	386·8	3·0
396·8	2·3	396·8	3·0	396·8	2·6	396·9	2·8
410·1 *a*	2·1	410·2	2·2	410·1	2·6		
434·1	2·3	434·0	2·9	434·0	2·6	434·0	
436·3	3·0	436·4	3·1	436·3	2·8	436·4	
447·1	2·7						
463·9	2·5	436·9	2·8	464·0	3·2	464·2	
468·0	2·1	468·0	1·7	468·0	1·7	468·8	
472·0 *b*	2·0	472·0	2·1	472·2	2·2	472·1	
486·1	2·7	486·2	3·2	486·2	2·4	486·1	3·2
495·8	3·0	495·7	3·1	495·9	2·5	496·2	
500·7	3·0	500 6	3·1	500·7	3·1	500·7	

Remarks.

a This line was omitted in the December paper as uncertain. It has since then been easily seen and measured.

b In the same December paper the width of this line was quoted 4 μμ on August 24 and 27. This width covered the whole band, including outside weaker wings. On the later dates of this table only the central stronger part is entered, because there is no decided termination of the violet-side extension. The appearance is rather that of a light background to the two bands 468 and 472, reading from 467 to 474, and too strong to be reckoned as continuous spectrum.

In Tables II. and III. some of the finer details are presented for further comparisons. Here also there is a general close agreement; but not without exceptions, which seem to be real

changes, although on account of the failing light of the star, they may be only photographic imperfections. These apparent changes are, in Table II., the relative intensities of the lines 469 and 471 in November and December; and in Table III. the reappearance of lines crossing Hγ.

TABLE II.

Brighter lines in region 467–474.

Aug. 27. λ μμ	Oct. 6	Nov. 22.	Dec 20
467·3	467·5	467·3 w	467·5
468·6 *c*	468·8	469·1 w	468·8 ss
470·0	470·3 w	470·3 ?	? *d*
471·2 ss	471·3 s	471·2 w	471·3 s
472·7 s	472·9	472·7 w	472·8

Remarks.—ss = very strong. s = strong. w = weak.

c By an error of copy from the original tabulations this line went to the press for the December paper as 468·1 instead of 468·5. The figures in this column are by remeasurements, which have given 470·0 and 472·7 greater than the former measures by 0·2 and 0·3 μμ.

d The uncertainty indicated here by the ? is owing to a scratch through the position where the line might be.

TABLE III.

Brighter lines in region 432–438.

	Sept. 5, Oct. 6. λ μμ.	Nov. 22. λ μμ	Dec. 20. λ μμ
		432·7	432·7
Hγ		433·6	433·9
		434·4	
	435·2	435·2	435·0
436·3	435·9	436·1	
	436·6	436·5	
	437·4	437·5 ?	

The structure of the bands at 386·8 and 396·9 has remained probably quite constant. This structure was given in the December paper as four bright components. At that time there was some doubt about the fourth component, whether it was divided or not. Subsequently greatly enlarged photographs showed the *five* components of the band at 386·8 on September 5, and of both bands on October 4 and 6, and November 22. Again, on December 18, the five components were very clearly marked on the more refracted band, but the companion band at 396·9 was not strong enough to show more than four bright parts, the fourth being relatively broad and very weak. And, similarly, on the plates of January 30 and 31 of this year only three of the components can be seen in the band 386·8, the less

refracted band being much too weak to show details. All through this series of photographs the more refracted of the two bands has been the stronger, and the stronger components of each have been of shorter wave-lengths.

The band at 495·9 on December 20 contains two sharply defined brighter lines near its edges, at 495·1 and 497·0; and the same marking, near the edges, appears in Hβ and in the band 500·7. The photograph of this date was by a remarkably successful exposure in a very clear sky, and compares well with the photograph of August 27. On a careful re-examination of this plate the same structure has been found in the bands 495·9 and 500·7, but only doubtfully in Hβ.

Stonyhurst College Observatory:
1902 *May.*

Series in the Nebular Spectrum, and in the Bright-Line Spectrum of Nova Persei. By E. F. J. Love, M.A., Assistant Lecturer and Demonstrator of Natural Philosophy in the University of Melbourne.

§ 1. *Introductory.*

Soon after the spectrum of Nova *Persei* had assumed the nebular type, Lockyer * and Sidgreaves † called attention to the abnormal brightness of three of the lines, compared with that of the "chief" nebular line at λ 5007; Sidgreaves further showed that these lines were characterised, in the Nova spectrum, by identity of structure, while the other lines present had a very different appearance. The wave-lengths of these lines, as estimated by different observers, group round the values λ 4363, λ 3968 and λ 3869.

It seemed to me likely that three lines so closely resembling each other might belong to a series of the general type investigated by Kayser and Runge; I therefore made the attempt to find one, with the results detailed in this paper.

§ 2. *Deduction of Series, and Comparisons with Nebular Lines.*

Since the identification of the lines above-mentioned with nebular lines seems to be beyond dispute, I preferred to use their wave-lengths as measured in nebular spectra, since these have recently been redetermined with great exactness at the Lick Observatory ‡ by Wright, in the course of the observations on

* *Proc. Roy. Soc.* vol. lxix. p. 133; *Monthly Notices*, vol. lxii. App. p. 1.
† *Monthly Notices*, vol. lxii. p. 137.
‡ *Astrophysical Journal*, vol. xiv. p. 267.

Nova *Persei*. The values given by him are 4363·3, 3967·6 and 3868·9; these I find to be included in a series of the form

$$\lambda^{-1} = A + Bn^{-2} - Cn^{-4}$$

where λ^{-1} denotes the number of waves per centimetre, A = 25739, B = 43108, C = 1412208, and n has the values 4, 5 and 6 for the three lines. The series relation therefore exists.

Recalling the important fact that the relative intensity of these lines increases as we go towards the violet—exactly the reverse of the usual behaviour of series lines *—it seemed worth while to extend the series, and see if it included other bright nebular lines. Making the calculation I find that $n = 8$ gives the wave-length † of a line observed by Campbell ‡ in the spectrum of the *Orion* nebula, while among higher members of the series I find wave-lengths corresponding to those of a number of lines observed by Huggins § in the spectrum of the trapezium stars and surrounding parts of the *Orion* nebula. Going in the other direction, I find that $n = 3$ gives a wave-length so far down in the extreme red—it corresponds nearly to the middle of the A band in the solar spectrum—as to be extremely difficult to observe in a nebular spectrum, supposing it were present.

The observed and computed values are collected in the following table; it must be noted that—except in the case of the three lines used in deducing the formula—the wave-lengths are only given, by the several investigators, to the nearest tenth-metre.

TABLE.

n	λ^{-1} calcd. (waves per cm.)	λ calcd. (tenth-metres.)	λ obsd. (tenth-metres.)	Observer.	Notes.
3	13104	7631·3	...	...	Not observed.
4	22917	4363·3	4363·3	Wright.	Used to deduce the formula.
5	25204	3967·6	3967·6	„	
6	25847	3868·9	3868·9	„	
8	26068	3836·1	3836	Campbell.	Orion nebula.
10	26029	3841·9	3842	Huggins.	Orion nebula and trapezium.
13	25945	3854·3	3854	„	„ „ „
If it be legitimate to include $n + \frac{1}{2}$, we obtain two other identifications.					
11·5	25985	3848·4	3848	Huggins.	Orion nebula and trapezium.
14·5	25912	3859·2	3859	„	„ „ „

* Can the positive sign of the term involving B—which is also the reverse of the usual case—be connected with this fact?

† The minimum possible wave-length for the series; proved by differentiating the equation.

‡ *Astronomy and Astrophysics*, vol. xii. p. 273.

§ *Proc. Roy. Soc.* vol. xlvi. p. 40.

The inclusion of the last two lines seems legitimate, as it introduces a symmetry in the values of n which would not otherwise exist; we may then, starting from $n = 8$, arrange the lines in two groups, the successive differences being

$$(n = 8)\begin{cases} 2,\ 1,\ 1,\ 1. & \text{First group.} \\ 2,\ 1\tfrac{1}{2},\ 1\tfrac{1}{2},\ 1\tfrac{1}{2}. & \text{Second group.} \end{cases}$$

It seems inadvisable to carry the table further; if n exceed 15, an increase of a unit in its value changes the wave-length by only $2\frac{1}{2}$ tenth-metres; if it exceed 20, we obtain values which might fit almost any line, between λ 3868 and λ 3885, not very accurately measured.

§ 3. *Remarks on the Identifications in the Table.*

1. Campbell identifies λ 3836 with β (otherwise known as $H\eta$), but this seems to me very doubtful. At the time of his observations everyone believed λ 3968 to be $H\varepsilon$, but this is now known, from Wright's investigation, to be a mistake; $H\varepsilon$ is indeed present, side by side with an "unknown" line, but it is very faint, while its unknown companion is bright; hence $H\eta$, if present at all, should be a still fainter line, but Campbell marks λ 3836 as "bright" in his table. It is true that he also identifies another bright line, at λ 3889, with α (or $H\xi$); but in view of the behaviour of $H\epsilon$ this may be attributed—with at least equal probability—to helium,* which has a strong line at λ 3888·8. Moreover the differences between the wave-lengths of the ultra-violet hydrogen lines and those identified with them by Campbell are much larger than any of the differences in the case of other, and quite certain, identifications; judging from these I find it much easier to believe some of Campbell's identifications wrong than to believe that his measurements are incorrect by three and four tenth-metres.†

2. Huggins's lines form part of a cluster, distinct and fairly strong in the spectrum of the trapezium stars, and extending into that of the surrounding nebula; so far they have not been obtained from other parts of the nebula. Two of the cluster, λ 3832 and λ 3825, do not belong to the series. Another line, equal in length on the plate to those identified above,‡ and of about the same order of brightness—measured by Huggins as λ 3870—is possibly identical with λ 3869; but this seems

* The helium spectrum was not known at the time of Campbell's observations; we have since learnt that it accounts for a number of lines in the spectrum of the Orion nebula.

† In view of the above arguments I am inclined to think that the hydrogen series, beyond $H\epsilon$, has probably not yet been detected in nebular spectra.

‡ And therefore, presumably, emitted from the same part of the nebula.

improbable, as neither the lower members of the series, nor λ 3836, are represented in the photograph.*

University of Melbourne:
1902 *March* 18.

Discovery of Comet Brooks, 1902. By William R. Brooks, D.Sc.

I have the honour to announce to the Society the discovery of a new comet.

While sweeping the eastern sky on the morning of April 14, I picked up an object in *Pegasus*, which I at once suspected to be a comet. Its position at $21^h\ 5^m$ G.M.T. was approximately R.A. $22^h\ 55^m\ 40^s$, Decl. $+29°\ 12'$. A slight haze and advancing twilight made me hesitate about making a public announcement, but a telegram was sent that morning to Harvard College Observatory of the suspected object.

The following morning was awaited with much interest, which fortunately was clear. The object, it was immediately noticed, had moved from the discovery field and was soon found about three degrees nearer the Sun. Its place on April 15, 21^h G.M.T., was R.A. $23^h\ 8^m\ 10$, Decl. $+27°\ 25'$. This gave a daily motion of about 12^m east and 2° south.

The comet is a fairly bright telescopic object. It has a very minute stellar nucleus and a short narrow tail.

Comet *Brooks*, 1902.

Smith Observatory, Geneva, N.Y.. U.S.A.

* The double grouping, exhibited in § 2, may account for the absence of the other radiations from this part of the nebula, and of these from other portions where they are present.

Micrometrical Measures of Double Stars with the 17½-in. Reflector.

By the Rev. T. E. Espin, M.A.

I.—*Stars of the Mensuræ Micrometricæ.*

In the following list Column 1 gives the number in Σ, Column 2 the approximate R.A. and Decl. for 1880, Column 3 the position angle, Column 4 the distance, Column 5 the number of nights, Column 6 the magnitudes, Column 7 the date, Column 8 notes.

Σ	R.A. 1880. h m	Decl. ° ′	P. °	D. ″	Nights.	Mags.	Date.	
16	0 10·3	+54 0	37·24	5·75	3	...	00·99	
30	20·7	+49 19	301·20	18·25	3	7·0 8·4	99 98	Note 1.
45	32·1	+46 18	87·25	13·43	2	7·5 9·5	00·60	Note 2.
59	41·2	+50 47	150·87	1·79	2	...	00·38	AB motion.
			124·87	34·71	2	$c=12·2$	00·38	AC. C and D not observed before.
			160·00	10·40	1	D 12·7	00·87	CD.
97	1 5·2	+50 53	97·35	5·05	2	8·9 9·2	99·96	
115	15·7	+57 30	148·61	1·15	3	7·0 7·3	01·61	Increase of distance.
268	2 21·0	+55 0	130·97	2·66	2	6·0 8·0	01·88	
270	22·4	+55 1	303·81	20·73	3	...	01·57	
296	36·0	+48 43	299·74	17·40	3	4·0 10·0	00·36	θ Persei. AB note.
			223·91	...	2	...	00·07	AC.
301	39·1	+53 26	16·34	8·05	4	...	01·00	
314	44·4	+52 30	303·23	1·42	3	6·8 7·0	00·62	Motion in angle.
331	52·5	+51 52	84·66	11·89	2	...	00·02	
388	3 20·1	+50 1	206·66	3·00	4	8·2 9·0	01·91	Motion in angle.
389	20·5	+58 57	63·42	2·56	4	...	02·07	Motion doubtful. Note.
390	20·9	+55 2	159·34	14·96	2	5·0 10·0	99·99	C.P.M.
396	23·9	+58 22	242·70	20·24	1	...	02·05	
398	24·6	+57 53	330·10	9·46	1	11·0 11·0	02·08	Note.
476	53·6	+38 20	286·46	20·56	2	7·5 8·4	99·94	Increase of angle and distance.
613	4 50·2	+43 57	104·50	16·63	4	8·2 9·0	00·29	AB. Note.
			17·74	15·91	5	11·0	00·25	AC
619	52·1	+50 5	122·72	5·47	3	8·0 8·3	00·35	Note.
845	6 2·4	+48 44	353·65	7 90	3	6·0 6·5	00·42	41 Aurigæ.
918	24·4	+52 33	327·30	4·73	2	7·0 7·3	00·09	Increase of angle.
1062	7 13·1	+50 22	315·50	14·59	2	...	00·58	19 Lyncis. Increase of angle.
1176	58·1	+42 19	28·30	22·29	2	8·3 9·3	00·59	

Σ	R.A. 1880. h m	Decl. ° ′	P. °	D. ″	Nights.	Mags.		Date.	
1312	9 1·8	+52 54	147·75	4·28	2	...		01·10	
1321	6·2	+53 12	65·05	18·96	2	7·1	7·5	00 08	Note.
			65·55	18·77	4	...		01·11	
			65·13	18·60	3	...		02 19	
1341	14·3	+51 7	267·44	20·69	3	8·5	8·6	01·11	
1366	27·4	+53 51	323·80	7·88	3	8·0	9·1	02·22	
1368	27·8	+53 51	220·44	21·12	2	8·3	9·6	02·21	
1402	56·8	+56 4	100·60	24·90	2	6·9	7 7	00 12	Note.
1427	10 14·7	+44 30	216·76	9·80	2	7·0	7·2	01·20	
1462	35·6	+51 25	172·28	7·77	2	7·2	9·5	01·65	
1486	47·9	+52 46	101·65	28·86	2	...		00·59	
1495	52·4	+59 35	37·77	34·10	2	6·7	8·4	01·65	
1543	11 22·6	+40 0	2·18	5·26	2	5·0	8·8	02·25	Motion.
1553	30·0	+57 48	166·42	5·00	2	7·3	7·7	02·28	
1572	40·6	+53 58	289·15	10·20	2	8·4	9·2	01·82	
1608	12 5·5	+54 5	223 06	11·91	2	7·5	7·7	01·35	
1630	13·0	+57 2	168·29	2·73	2	9·0	9·2	01·82	
1662	30·2	+57 14	234·95	19·74	2	...		01·82	Motion.
1718	13 0·2	+51 37	272·06	13·21	2	8·8	9·0	01·37	
1758	27·9	+49 45	305·37	4·47	4	7·1	7·2	00·90	Motion.
1821	14 9·2	+52 21	236·78	12·74	2	4·2	8·5	00·93	κ Boötis.
1843	20·2	+48 22	186·63	20·35	2	...		01·37	
1909	59·9	+48 7	243·56	4·74	4	7·0	7·2	01·41	Motion.
1984	15 48·0	+53 16	276·93	6·92	4	6·3	8 5	01 17	Motion.
2015	16 5·2	+45 40	158·68	3·24	3	...		01·05	AB.
			96·84	14·21	2	$c=13·2$		01·37	AC. Not seen before, difficult.
2060	26·2	+47 32	255·28	5·34	2	8·7	8·8	01·45	
2063	28·2	+45 51	195·75	16·42	3	5·5	8·1	01·08	
2068	30·5	+47 32	255·28	5·34	2	8·7	8·8	01·45	
2072	32·2	+47 56	180·19	5·46	3	8·6	9·1	01·16	Motion.
2078	33·4	+53 10	109·54	3·48	3	5·0	5·5	01·16	17 Draconis.
			194·52	90·55	2	...		00·44	16 and 17 Draconis
2082	35·5	+49 10	91·11	23·74	4	4·5	9·4	00·71	
2130	17 2·9	+54 37	326·87	2·35	3	5·0	5·2	01·16	μ Draconis.
2138	7·7	+54 39	135·55	22·32	2	8·0	8·7	00·97	
2271	57·7	+52 51	267·31	2·37	3	6·9	7·8	00·88	
2277	18 0·0	+48 28	121·45	26·91	2	6·5	8·4	01·68	Motion.
2278	0·8	+56 26	24·22	37·04	2	7·0	7·4	00·55	AB.
			147·29	6·32	2		7·7	00·55	BC.

Σ	R.A. 1880. h m	Decl. ° ′	P. °	D. ″	Nights.	Mags.		Date.	
2323	22·2	+58 43	357·53	3·47	2	...		01·16	Motion.
2348	31·2	+52 16	272·23	25·42	2	5·5	7·8	01·52	
2393	41·1	+38 12	22·70	13·56	7	7·1	9·6	00·36	Increase of distance.
2433	54·7	+56 35	125·41	7·53	2	7·2	10·0	01·66	
2463	19 2·5	+45 37	4·08	9·55	3	8·5	9·2	01·03	Motion.
2507	16·0	+44 9	139·18	25·80	2	7·7	9·2	01·74	AB.
			283·80	7·14	2		10·0	01·74	BC motion? *h*'s star.
2580	41·9	+33 27	70·90	25·59	2	...		01·17	χ Cygni, motion.
2588	45·2	+44 4	160·86	9·90	2	...		01·72	
2609	54·2	+37 47	24·62	2·42	3	...		01·60	
2619	57·5	+47 56	244·61	4·05	2	8·0	8·0	01·63	AB. Note.
			300·24	11·03	3		13·7	01·64	BC.
			300·15	16·72	3		12·0	01·81	AD.
			321·09	16·48	4	...		01·73	BD.
			164·4	...	1	...		01·81	DC.
2708	20 34·1	+38 13	27·40	18·63	2	7·0	13·5	01·60	AB, Hall's star. Note.
			330·92	27·87	3		8·5	01·59	AC.
2773	21 5·8	+43 32	115·95	3·41	2	8·3	8·7	01·64	
2789	16·7	+52 28	296·10	6·01	3	7·0	7·1	01·01	
2813	32·4	+56 56	272·27	10·29	3	8·8	9·0	01·08	
2815	34·0	+57 1	79·76	7·32	3	7·8	9·5	01·08	
2840	48·0	+55 14	195·66	19·71	4	6·0	6·5	00·38	
2902	22 18·5	+44 45	88·07	6·07	3	7·8	8·1	01·72	
2987	23 4·8	+48 22	158·98	3·60	2	7·5	10·0	01·76	
3010	17·7	+45 8	132·26	25·65	2	8·3	8·6	01·71	AB.
			103·60	29·47	2		11·5	01·71	AC not seen before.
3034	38·6	+45 43	101·10	6·49	2	7·8	10·5	00·81	Motion?

Notes.

1 Σ 30. A Proper Motion of 0″·05 towards 265°·0 in the large star will explain the change.

2 Σ 45. A Proper Motion of 0″·064 towards 176°·0 is probable.

3 Σ 296. θ Persei. The motion during the 116 years since Herschel's observation is perfectly rectilinear. I find the following:—

A 0″·338 in the direction of 105°·6
B 0″·319 „ „ „ 100°·6

and all the observations are well represented by

Δ $16''{\cdot}363 + 0''{\cdot}029(t - 1866{\cdot}0)$
P $297°{\cdot}162 + 0°{\cdot}075(t - 1866{\cdot}0)$

The star C has no connection with the system.

389. The measures of this star are most discordant. It seems probable that so far there is little if any motion.

398. De. did not measure this star, and it has been generally neglected. It is too faint to be in the B.D. It lies 33°*f* 2′ *s* of B.D + 57°, 729, which has a very faint comes (too faint to measure satisfactorily with the 17½-in.).

AB P. 325°·46. D 6″·88. Mags. 8·0 13·5 1902·08.

Σ 613. A has a Proper Motion of 0″·047 towards 114°·7.
Σ 619. A change of 16°·7 in angle since Σ.
Σ 1321. A system like 61 Cygni P.M. A 1″·711 towards 249°·1.
B 1″·742 „ 247°·0.

The later observations show that Dunér's formula is correct for position, but makes the distance too large according to recent measures. The following gives closer agreement:

$$\Delta = 19''\cdot721 - 0''\cdot02(t - 1863\cdot0)$$
$$P = 55°\cdot69 + 0°\cdot24(t - 1863\cdot0)$$

The star C was first seen 1901 Jan. 22: it is too faint to measure satisfactorily with the 17½-in. A and B are both strong reddish yellow.

Σ 1402. A has apparent Proper Motion 0″·07 towards 123°·5.

Σ 2619. The star D was first seen by *h*, and has been measured by OΣ and *β*. The star C was detected by OΣ. The comites are difficult to measure with the 17½-in. The position-angle DC was obtained by setting the wire parallel with the stars.

Σ 2708. The star B was detected by Professor Hall, and is called by him 15 mag. It was detected independently with the 17½-in. It is too faint to measure properly, but the measures are sufficient to show that the change is due to the Proper Motion of A. The various measures show that A has a Proper Motion of 0″·26 towards 137°·7 which is in close agreement with the meridian observations.

II.—*Various Stars.*

(C. A. G. refers to stars found double in the catalogue of the *Astronomische Gesellschaft.*)

Names.	R.A. 1880 h m	Decl. ° ′	P. °	D. ″	Nights.	Mags.		Date.	Notes.
Espin 40 ...	0 5·1	+ 51 24	72·88	3·27	2	8·7	11·7	02·03	AB.
			316·84	23·50	2		10·0	02·03	AC.
Espin 42 ...	16·3	+ 52 56	191·28	10·36	3	8·3	9·3	01·90	
OΣΣ 7 ...	40·0	+ 50 26	76·08	50·59	2	7·5	7·7	01·97	
Σ 83 rej. ...	56 5	+ 49 40	313·50	22·09	3	7·7	10·4	00·32	*h* 311°·1.
Dawes 8 ...	1 15·3	+ 43 11	140·99	2·47	2	8·5	9·0	00·98	No change.
Σ 190 rej.	50·8	+ 40 48	75·22	24·12	2	8·2	9·2	00·03	Separating from PM.
h 2136 ...	2 21·0	+ 53 19	34·74	5·02	3	8·6	9·2	00 93	*h* 37°·1
Holmes ...	3 20·0	+ 59 30	49·94	5·40	3	8·6	10·0	01·62	
OΣΣ 37 ...	30·0	+ 44 25	95·60	41·23	2	6·5	6·8	01·08	
Espin 55 ...	56·2	+ 58 58	261·30	9·01	2	8·1	12·5	01·98	A red.
Hussey 212	4 5·0	+ 51 31	192·29	3·66	3	8·9	10·0	01·06	AC found independently.
Goodacre ...	29·0	+ 16 16	331·25	3·73	2	11·7	11·7	01·13	Note.
h 2241 ...	48·9	+ 47 49	263·14	11·59	3	9·0	9·1	00·66	
C. A. G. ...	52·7	+ 54 39	159·99	4·21	2	8·8	9·2	00·56	

Names.	R.A. 1880 h m	Decl. ° ′	P. °	D. ″	Nights	Mags.		Date.	Notes.
h 2319 ...	6 24·9	+47 52	305·88	3·58	2	9·1	10·7	00·51	AB. *h* 300°·5.
			259·40	15·81	2		13·0	00·51	AC.
OΣΣ 78 ...	38·1	+43 42	24·58	45·39	4			00·34	Change from PM.
C. A. G. ...	50·8	+57 1	174·28	6·95	2	9·1	9·2	00·09	AB.
			3·62	15·46	2		14	00·09	AC. Very difficult.
h 2399 ...	7 29·7	+57 3	66·15	12·26	2	8·7	11·7	00·09	
Hussey 224?	8 12·6	+47 47	323·10	3·80	2	8·0	11·5	01·17	Note.
C. A. G. ...	46·2	+50 21	336·90	5·44	2	8·9	9·0	01·21	
h 1176 ...	10 8·6	+58 2	318·50	8·90	2	9·0	9·2	02·29	
h 2545 ...	42·0	+55 55	111·11	18·96	3	8·8	11·2	02·27	*h* 116°·3.
OΣΣ 109 ...	11 9·1	+46 31	256·83	79·25	2	6·9	7·7	02·31	
Σ 1563 rej.	32·8	+52 50	157·10	13·54	2	8·6	10·8	02·29	
Espin 73 ...	12 4·3	+55 35	305·81	3·64	3	10·5	10·7	01·68	BC.
			20·87	31·25	3		8·2	01·67	AB.
h 2617 ...	34·9	+40 56	3·61	6·24	2	8·1	8·8	02·31	Motion.
h 2627 ...	52·2	+48 7	132·15	17·77	2	8·8	10·9	01·14	
Holmes ...	13 26·8	+36 56	163·43	7·30	2	9·1	9·5	01·84	
h 1234 ...	29·3	+39 24	23·38	33·36	3	7·5	11·3	02·31	
C. A. G. ...	30·8	+50 16	14·09	3·30	3	8·9	9·1	00·41	
			9·19	3·17	4			02·30	
h 2700 ...	14 0·8	+40 33	216·23	22·33	2	8·7	12·7	00·89	
H*h* 435 ...	3·8	+50 2	274·20	81·15	2	4·7	11·0	02·29	13 Boötis. Note.
h 540 ...	5·4	+36 23	209·84	9·04		8·8	9·1	02·32	Note.
Σ I. 26 ...	11·9	+51 55	33·41	38·12	2			01·40	*i* Boötis.
Espin 19 ...	16·2	+52 13	41 66	1·62	3	9·2	10·5	02·32	AB. Very difficult.
			170·38	41·91	3		9·3	02·32	AC.
h 2716 ...	18·4	+46 55	85·88	5·02	2	9·1	9·3	02·28	
h 2729 ...	26 3	+56 39	56·15	27·52	2	8·7	11·0	01·36	
Sh 191 ...	56·0	+54 21	343·15	40·00	3	6·6	7·0	00·75	
OΣΣ 137 ...	15 12·2	+51 23	105·82	74·14	2	6·1	8·6	00·50	
C. A. G. ...	16 0·6	+49 17	254·81	8·19	3	9·3	9·4	00·38	
Ho 412 ...	17 3·8	+36 6	140·42	19·78	2	5·0	11·2	00·56	
Σ 2209 rej.	39·2	+43 13	128·06	29·17	2	7·7	9·7	00·66	
h 1354 ...	18 48·8	+36 17	5·97	9·87	2	8·8	8·9	00·54	*h* 187°·0.
H*h* 603 ...	19 1·7	+35 42	54·95	45·52	1	7·5	8·7	00·57	
Aitken 152.	7·4	+36 49	257·00	2·71	3	9·1	9·2	01·58	AB. Note.
			175·00	20·67	3		10·3	01·58	AC.

Names.	R.A. 1880	Decl.	P.	D.	Nights.	Mags.		Date.	Notes.
	h m s	° ′	°	″					
H*h* 605 ...	9·4	+ 38 50	57·07	39·35	2	7·5	7·8	00·53	
Aitken 157	12·0	+ 37 10	142·74	2·13	3	9·0	10·0	01·58	Note.
Aitken 158	12·5	+ 38 58	292·53	3·50	3	8·4	9·7	01·58	Note.
h 1506 ...	20 18·6	+ 35 18	202·27	9·02	2	8·3	10·5	00·66	AB. *h* 199°·5.
			192·55	32·67	1		10·3	00·66	AC. *h* 191° 1.
C. A. G. ...	41·1	+ 36 20	214·25	6·30	3	9·1	9·2	00·67	
S 786 ...	21 15·8	+ 52 33	300·40	47·18	3	7·6	9·0	01·01	
h 1709 ...	54·0	+ 56 1	316·76	9·20	2	8·9	12·0	00·66	*h* 312°·9.
H*h* 764 ...	22 24·1	+ 57 38	9·81	25·03	2			99·86	P δ Cephei.
C. A. G. ...	27·6	+ 54 35	333·79	2·86	3	8·7	9·1	01·03	
Dembowski	29·4	+ 49 46	348·42	7·88	4	8·3	8·4	01·07	
h 1849 ...	23 2·2	+ 45 43	347·59	47·54	2	4·7	11·0	01·82	4 Andromedæ.
OΣΣ 248 ...	40·8	+ 50 0	339·40	23·23	1	6·5	12·0	01·83	AB not seen before.
			140·15	53·24	1		9·0	01·83	AC.
Holmes ...	52·4	+ 57 0	75·86	18·61	2	8·0	11·0	01·92	
Espin 112	53·1	+ 52 49	221·80	1 33	4	9·0	9·2	01·99	
OΣΣ 254 ...	55·0	+ 59 43	269·45	58 95	1	7·0	8·5	00·86	

Notes.

Goodacre. A little pair 62 sec. *p* α Tauri. Place of α Tauri.

Hussey 224. Found independently, and measured before Hussey's results reached me. Hussey makes the star *p* the double, and my angle differs by 10°. It is a very difficult object.

H*h* 435. I have failed to find any comes in H's place (82°·6).

h 540. *h* gives (*hMm* 312) 1828·33 30°·18, 14″·19, but in his second catalogue the distance is estimated at 6″.

Aitken 152, 157. 158. These three stars were all detected and measured before Aitken's results reached me.

The following stars I have been unable to find:

		h	m	°	′			
h 2373	...	7	15·5	+ 56	21	(1880)	00 Jan.	27, Feb. 5.
h 1222	...	12	46 8	+ 47	26	„	02 Apr.	22
H*h* 495	...	16	1·2	+ 42	20	„	00 June	8
H*h* 635	...	19	40·2	+ 37	15	„	00 July	10
h 1481½	..	20	2·6	+ 32	14	„	00 Sept.	14
Mayer	...	21	4·0	+ 52	12	„	00 Aug.	14
H*h* 724	...	21	12·0	+ 37	16	„	00 „	16
h 1773	...	22	23·4	+ 58	17	„	01 Jan.	5

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXII. JUNE 13, 1902. No. 8

Dr. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair.

Henry Bridger Adames, 5 West Street, Chichester, Sussex, was balloted for and duly elected a Fellow of the Society.

The following Candidate was proposed for election as a Fellow of the Society, the name of the proposer from personal knowledge being appended :—

George McKenzie Knight, 27 King Henry's Road, South Hampstead, N.W. (proposed by Walter E. Besley).

Seventy-eight presents were announced as having been received since the last meeting, including amongst others :—

G. Bigourdan, Sur la prédiction des occultations des étoiles par la Lune &c. ; G. Bigourdan, Observations des nébuleuses et d'amas stellaires, 2 vols., presented by the author ; A. G. Pingré, Annales célestes du dix-septième siècle, publié par G. Bigourdan, presented by the editor ; Preliminary report of the Dutch expedition to Sumatra for the observation of the total solar eclipse of 1901 May, and report of the Dutch observations, No. 12, presented by the Dutch Eclipse Committee ; Royal Society catalogue of scientific papers, 1800–1883, supplementary volume, presented by the Society ; Solar Physics Observatory, catalogue of 470 of the brighter stars classified according to their chemistry, presented by the Observatory ; W. F. Wislicenus, Astronomischer Jahresbericht, 1901, presented by the author.

Comparison of Groombridge's and Struve's Right Ascensions of close Circumpolar Stars. By W. G. Thackeray.

(*Communicated by the Astronomer Royal.*)

How general was the idea that Groombridge's meridian mark was in error is clear from the positive statements made by Dr. Gould in his papers "On the Mean Places of forty-eight Circumpolar Stars," *Astronomical Journal*, Nos. 121, 122, and 130. On p. 1, No. 121, vol. vi., he remarks: "Since there can be no doubt that Groombridge's meridian mark was in error about $2\frac{1}{2}''$," and again on p. 10, No. 122: "right ascensions which, despite the skill and zeal of Piazzi and Groombridge, were referred to erroneous meridian marks." The basis of these positive assertions were the results of the comparison of Struve's and Argelander's observations with those of Groombridge made by Fedorenko and Struve, and which are

$$\text{Argelander-Groombridge} = +0^s{\cdot}154 + 0^s{\cdot}188 \tan \delta$$
(Fedorenko, p. 8).

$$\text{Struve-Groombridge} = +0^s{\cdot}036 + 0^s{\cdot}130 \tan \delta$$
(Pos. Med. p. cxxviii).

It was Prof. Safford who first (*Monthly Notices*, xlvii. 2, pp. 37–42) sounded a note of doubt on the subject. Dividing the stars common to Struve's and Groombridge's catalogue in four zones he showed that the resulting differences varying but little with the declination, are subject to rather large casual errors, and concluded that "there is but little doubt that the main cause of the discrepancy is instrumental error," and further remarked that "Groombridge's meridian mark was rather too near—about half-mile off—and a previous investigation of Maskelyne's and Pond's observations has shown me that a polar deviation of $\pm 1''$ is not altogether to be avoided when the instrument is adjusted to the meridian from time to time and left for days to its own motions without allowing for azimuth and level error in the modern fashion."

The results of the new reduction of Groombridge's observations for all observations made up to the end of 1810 engrafted on Prof. Safford's paper in the form of corrections conclusively show how right Prof. Safford was in his deductions, and that there is no evidence to support the contention that Groombridge's mark was out of the meridian.

Columns 3 and 4 give respectively the old catalogue and newly reduced place of Groombridge's observations, column 5 the corrections to the old catalogue place, and column 7 the corrected discordance between Struve and Groombridge.

The deduced results of the discussion compare as follows:—

	Mean $\Delta\alpha \times \cos\delta$.	P.E. of one Star.	P.E. of a Groombridge Star.
	s	s	s
Safford original ...	+0·034	±0·093	±0·084
„ corrected ...	−0·026	±0·063	±0·049

The probable error of a Groombridge star was obtained by Professor Safford on the supposition that a liberal allowance for errors of observations in the case of Struve would be $\pm 0^s{\cdot}04$.

Zone +86° *to* +90°.

Groomb. No.	Polar Dist.	Secs. of Groomb. Old.	Secs. of Groomb. New.	New minus Old.	Safford. $\Delta\alpha$ Struve-Groomb.	Safford. $\Delta\alpha$ corrected.	Safford. $\Delta\alpha \cos\delta$ corrected.
	°	s	s	s	s	s	s
144	2·0	34·75	34·97	+0·22	− 1·82	−2·04	−0·07
235	1·7	37·56	39·10	+1·54	+ 0·40	−1·14	−0·03
642	4·0	6·04	6·04	0·00	− 1·14	−1·14	−0·08
1119	0·9	41·13	31·83	−9·30	−12·05	−2·75	−0·04
1141	2·7	58·61	52·94	−5·67	− 3·73	+1·94	+0·09
1850	3·4	48·47	48·62	+0·15	+ 1·09	+0·94	+0·05
1871	2·5	10·11	7·63	−2·48	− 0·67	+1·81	+0·07
1884	1·3	48·37	42·10	−6·27	− 0·93	+5·34	+0·12
2006	1·4	54·33	58·60	+4·27	+ 3·29	−0·98	−0·02
2065	1·5	55·71	64·64	+8·93	+11·80	+2·87	+0·07
2099	3·4	38·56	41·77	+3·21	+ 3·71	+0·50	+0·03
2210	3·3	22·65	24·07	+1·42	+ 3·88	+2·46	+0·14
2283	2·1	17·78	16·57	−1·21	+ 1·63	+2·84	+0·10
2628	3·4	28·63	29·18	+0·55	+ 0·07	−0·48	−0·03
2667	3·1	44·40	45·81	+1·41	+ 0·45	−0·96	−0·05
3308	1·3	41·23	43·27	+2·04	+ 1·83	−0·21	0·00
3548	3·7	46·98	47·84	+0·86	+ 0·88	+0·02	0·00
4101	3·7	39·78	40·44	+0·66	− 0·35	−1·01	−0·06

Zone +83° *to* +86°.

67	4·7	0·19	2·60	+2·41	+ 0·79	−1·62	−0·13
177	4·8	49·23	49·98	+0·75	+ 0·20	−0·55	−0·04
595	5·8	30·00	31·77	+1·77	+ 2·49	+0·72	+0·07
750	5·0	20·22	21·31	+1·09	+ 0·47	−0·62	−0·05
766	6·7	28·24	29·26	+1·02	+ 0·44	−0·58	−0·06
944	4·9	18·76	18·69	−0·07	− 0·83	−0·76	−0·06
956	4·8	21·23	24·37	+3·14	+ 2·63	−0·51	−0·04
1359	5·4	50·28	46·47	−3·81	− 5·56	−1·75	−0·16
1418	4·3	22·44	18·94	−3·50	− 5·72	−2·22	−0·17

Zone +83° *to* +86°.

Groomb. No.	Polar Dist.	Secs. of Groomb. Old.	Secs. of Groomb. New.	New minus Old.	Safford. Δα Struve-Groomb.	Safford. Δα corrected.	Safford. Δα cos δ corrected.
	°	s	s	s	s	s	s
1620	4·8	56·49	55·78	−0·71	+ 0·47	+1·18	+0·09
1633	6·5	42·14	41·84	−0·30	− 0·33	−0·03	0·00
1889	5·3	26·87	29·29	+2·42	+ 2·91	+0·49	+0·05
1937	5·6	45·56	46·69	+1·13	+ 1·15	+0·02	0·00
1940	5·6	53·71	54·04	+0·73	+ 1·76	+1·03	+0·10
2007	4·3	0·01	1·01	+1·00	+ 1·12	+0·12	+0·01
2063	6·3	23·09	23·49	+0·40	+ 1·24	+0·84	+0·09
2196	6·7	1·86	2·13	+0·27	+ 1·25	+0·98	+0·12
2213	5·3	14·42	15·73	+1·31	+ 1·98	+0·67	+0·06
2315	6·5	3·38	4·69	+1·31	+ 0·83	−0·48	−0·06
2476	6·6	20·33	21·15	+0·82	+ 0·56	−0·26	−0·03
2548	6·6	51·76	51·84	+0·08	− 2·10	−2·18	−0·24
3501	6·5	10·93	11·54	+0·61	− 0·30	−0·91	−0·10
3820	4·8	41·10	42·65	+1·55	+ 0·33	−1·22	−0·10
3824	4·7	18·00	19·81	+1·81	− 0·47	−2·28	−0·18
3970	6·6	27·78	29·65	+1·87	− 0·45	−2·32	−0·27
4193	4·3	57·57	58·90	+1·33	+ 0·20	−1·13	−0·08
				Zone +80° *to* +83°.			
424	9·6	47·48	48·35	+0·87	+ 0·94	+0·07	+0·01
426	9·4	24·62	25·40	+0·78	+ 1·28	+0·50	+0·08
506	9·2	17·72	17·53	−0·19	− 0·03	+0·16	+0·03
527	9·4	16·32	16·68	+0·36	+ 0·67	+0·31	+0·05
580	9·3	8·73	9·93	+1·20	+ 0·58	−0·62	−0·10
746	9·8	54·54	54·90	+0·36	− 0·05	−0·41	−0·07
774	7·1	22·37	23·27	+0·90	+ 0·43	−0·47	−0·06
779	9·6	37·00	37·30	+0·30	+ 0·47	+0·17	+0·02
785	9·5	48·19	48·94	+0·75	+ 0·52	−0·23	−0·04
856	9·1	19·05	19·82	+0·77	+ 0·99	+0·22	+0·03
1255	8·4	48·24	48·32	+0·08	− 1·17	−1·25	−0·18
1259	7·3	22·39	23·24	+0·85	+ 0·54	−0·31	−0·04
1278	8·8	30·12	30·45	+0·33	− 0·49	−0·82	−0·13
1339	9·3	17·77	17·49	−0·28	− 0·50	−0·22	−0·03
1355	9·7	4·96	6·19	+1·23	+ 0·56	−0·67	−0·12
1391	7·0	36·57	35·81	−0·76	− 0·85	−0·09	−0·01
1431	7·1	49·82	49·70	−0·12	− 1·81	−1·69	−0·21

Zone +80° *to* +83°.

Groomb. No.	Polar Dist.	Secs. of Groomb. Old.	Secs. of Groomb. New.	New minus Old.	Safford. Δα Struve-Groomb.	Safford. Δα corrected.	Safford. Δ cos δ corrected.
	°	s	s	s	s	s	s
1452	9·3	21·70	22·30	+0·60	− 0·56	−1·16	−0·19
1463	9·3	49·55	49·71	+0·16	− 0·83	−0·99	−0·16
1480	8·5	52·89	54·12	+1·23	− 0·08	−1·31	−0·19
1537	7·9	57·35	56·77	−0·58	− 1·46	−0·88	−0·12
1643	8·6	41·61	40·60	−1·01	− 0·85	+0 16	+0·02
1662	8·6	0·59	0·58	−0·01	− 0·36	−0·35	−0·05
1778	7·9	56·30	57·43	+1·13	+ 1·01	−0·12	−0·02
1782	7·9	55·13	55·33	+0·20	− 0·07	−0·27	−0·04
1845	8·1	3·92	4·58	+0·66	+ 1·86	+1·20	+0·18
1858	7·3	12·62	12·01	−0·61	− 0·13	+0·48	+0·06
1909	8·7	11·13	11·93	+0·80	+ 1·31	+0·51	+0·08
1927	8·4	35·80	36·07	+0·27	+ 1·34	+1 07	+0·16
1977	8·5	53·10	52·90	−0·20	+ 0·15	+0·35	+0·05
2037	8·7	46·07	46·30	+0·23	+ 0·05	−0·18	−0·03
2071	8·3	8·70	8·77	+0·07	+ 0·80	+0·73	+0·11
2275	9·0	41·80	42·65	+0·85	+ 1·93	+1·08	+0·17
2276	9·0	54·46	55·27	+0·81	+ 2·06	+1·25	+0·20
2422	7·7	51·28	52·02	+0·74	+ 0·29	−0·45	−0·06
2456	9·7	8·95	9·13	+0·18	+ 0·23	+0·05	+0·01
3268	9·2	17·30	17·52	+0·22	+ 0·40	+0·18	+0·03
3276	9·2	36 30	37·02	+0·72	+ 0·43	−0·29	−0·05
3277	9·6	55·19	55·65	+0·46	+ 0·33	−0·13	−0·02
3370	8·2	35·07	36·14	+1·07	+ 0·85	−0·22	−0·03
3707	8·4	25·24	25·71	+0·47	+ 0·23	−0·24	−0·04
3709	8·4	31·26	31·95	+0·69	+ 0·79	+0·10	+0·01
3887	9·6	46·32	47·37	+1·05	− 0·10	−1·15	−0·19
3928	7·8	52·99	54·19	+1·20	− 0·30	−1·50	−0·20

Zone +70° *to* +80°.

616	13·0	40·30	41·36	+1·06	+ 0·53	−0·53	−0·11
919	11·0	29·89	30·98	+1·09	+ 0·71	−0·38	−0·07
966	15·1	23·25	24·24	+0·99	+ 0·69	−0·30	−0·08
1217	12·8	9·94	10·97	+1·03	+ 0·63	−0·40	−0·09
1562	10·0	4·31	4·31	0·00	− 0·71	−0·71	−0·12
1650	13·3	33·02	35·18	+2·16	+ 0·98	−1·18	−0·26
1859	11·4	6·87	7·57	+0·70	+ 0·58	−0·12	−0·02

Zone +70° to +80°.

Groomb. No.	Polar Dist.	Secs. of Groomb. Old.	Secs. of Groomb. New.	New minus Old.	Safford. Δα Strave-Groomb.	Safford. Δα corrected.	Safford. Δα cos δ corrected.
	°	s	s	s	s	s	s
2094	11·6	47·11	47·06	−0·05	+ 0·10	+0·15	+0·03
2130	13·5	4·45	4·27	−0·18	+ 0·21	+0·39	+0·09
2172	15·1	22·80	23·35	+0·55	+ 0·65	+0·10	+0·02
2228	17·5	20·17	20·43	+0·26	− 0·09	−0·35	−0·10
2236	17·5	6·78	7·53	+0·75	+ 0·55	−0·20	−0·06
2268	12·0	16·82	18·16	+1·34	+ 1·46	+0·12	+0·02
2294	11·6	4·97	6·33	+1·06	+ 1·39	+0·33	+0·07
2334	13·7	23·80	24·15	+0·35	+ 0·28	−0·07	−0·01
2336	14 3	28·15	27·53	−0·62	− 0·69	−0·07	−0·01
2349	13·8	11·45	12·25	+0·80	+ 0·67	−0·13	−0·03
2475	17·8	20·32	20·46	+0·14	0·00	−0·14	−0·04
2477	17·8	22·04	22·10	+0·06	− 0·06	−0·12	−0·04
2546	10·0	17·75	12·82	−4·93	(− 4·92)	+0·01	0·00
2547	10·0	24·21	19·29	−4·92	(− 4·98)	−0·06	−0·02
2726	14·8	25·66	25·99	+0·33	+ 0·08	−0·25	−0·06
2930	16·0	1·14	1·72	+0 58	+ 0·43	−0·15	−0·04
3148	12·9	3·00	3·31	+0·31	+ 0·43	+0·12	+0·03
3373	10·1	48·72	48·10	−0·62	− 1·16	−0·54	−0·09
3419	12·6	3·55	4·17	+0·62	+ 0·16	−0·46	−0·10
3508	14·4	8·39	7·96	−0·43	− 0·75	−0·32	−0·08
3511	10·3	0·18	1·47	+1·29	+ 1·74	+0·45	+0·08
3809	12·2	9·65	8·86	−0·79	− 0 71	+0·08	+0·02
3831	12·1	5·42	4·51	−0·91	− 0·82	+0·09	+0·02
3834	14·7	53·22	...	...	− 0·74	...	...
4122	13·4	38·70	38·61	−0·09	− 0·04	+0·05	+0·01

From an independent comparison of the individual observations of some 35 stars spread over the four zones as shown below the p.e. of a Groombridge observation is $\pm 0^{s}\cdot053$:—

Zone.	East.	Wt.	No. of Stars.	West.	Wt.	No. of Stars.
° °	s			s		
90–86	±0·031	14	3	±0·047	28	5
86–83	±0·066	23	5	±0·056	12	3
83–80	±0·070	20	5	±0·061	23	5
80–70	±0·055	14	3	±0·062	28	6

The Distribution of the Stars of the Cape Photographic Durchmusterung. By A. M. W. Downing, D.Sc., F.R.S.

The publication of the C.P.D. is of peculiar interest as enabling us, for the first time, to attack the problem of stellar distribution on a sufficiently extended scale by a method which is free from many of the disabilities attaching to the older method of eye observing, although liable to other disabilities which affect the photographic method.

Thus the photographic plate is far more efficient than the eye in registering the stars to the same order of magnitude in the richer portions of the sky as in more sparsely occupied regions. On the other hand, the determination of a homogeneous system of stellar magnitudes by photography is a difficult and delicate operation.

Notwithstanding, therefore, the fact that M. Stratonoff has already published an instructive note on the subject in *Astron. Nachrichten*, No. 3710, I have thought that it would be of interest to astronomers to exhibit the general results of an analysis of the C.P.D. which I have made pending the publication of a further discussion of the registered stellar magnitudes which is expected from the authors, more especially as my work is carried out on somewhat different lines from those adopted by M. Stratonoff. In what follows the magnitudes of the catalogue are adopted throughout.

I have omitted the partial zone $-18°$, so that the stars whose distribution is here discussed all lie between $-19°$ dec. and the South Pole (Equinox 1875·0).

The first, and of course by far the most laborious, part of the work was to count the stars of different magnitudes occurring in each zone. The magnitude-groups adopted were (1) 0 to 6·2, (2) 6·3 to 6·7, (3) 6·8 to 7·2, (4) 7·3 to 7·7, (5) 7·8 to 8·2, (6) 8·3 to 8·7, (7) 8·8 to 9·2, (8) 9·3 to 9·7, (9) 9·8 to 10·2, and (10) 10·3 and fainter. The numbers in the last group were formed by simply taking the differences between the sums of the first nine groups and the total numbers for each zone. The group is relatively too limited in numbers of stars to be of interest to us in the present connection.

In order to avoid the inconvenience of using large numbers I have exhibited the results of the counts as "density," or number of stars in one square degree.

The first table gives the mean density corresponding to each magnitude-group and the ratio (ρ), corresponding to one stellar magnitude computed from the expression

$$n \log \rho = \log D_{m+n} - \log D_m$$

where D_{m+n} is the density from magnitude 0 to magnitude $m+n$, and D_m is the similar density to magnitude m.

It may be noted that the total number of square degrees comprised in the survey is 13,911·15, and that the aggregate mean density is 32·66. The total number of stars included in the table is 454,381.

TABLE I.

Range of Mag.	Mean Density.	Ratio.
0 to 6·2	·067	
6·3 „ 6·7	·058	3·48
6·8 „ 7·2	·158	5·13
7·3 „ 7·7	·346	4·94
7·8 „ 8·2	·861	5·61
8·3 „ 8·7	1·744	4·71
8·8 „ 9·2	4·619	5·90
9·3 „ 9·7	8·453	4·31
9·8 „ 10·2	12·254	3·07
10·3 and fainter	4·102	

No further reference will be made to the last magnitude-group.

It will be remembered that the authors claim that the survey is complete to mag. 9·2 only. The series of ratios given above would seem to substantiate this view, as there is a decided decrease after the above-mentioned limit is passed.

The next step in the discussion was to transform the places of the stars comprised in the different magnitude-groups to their galactic coordinates in order to investigate their distribution with reference to the galaxy. For this purpose the portion of the surface of the celestial sphere between −19° dec. and the South Pole was divided into zones of galactic latitude as follows :—

I. Latitudes -90° to -70°
II. Latitudes -70 to -50
III. Latitudes -50 to -30
IV. Latitudes -30 to -10
V. Latitudes -10 to $+10$
VI. Latitudes $+10$ to $+30$
VII. Latitudes $+30$ to $+43\frac{1}{2}$

The assumed position of the South Galactic Pole was R.A. $0^h\ 48^m$, dec. $-27\frac{1}{2}^\circ$.

The mean density in each zone was then found for each magnitude-group from the corresponding numbers of stars in each zone of declination and each hour of R.A.

The results of the transformation are exhibited in the following table, where mag. 6·5 means the magnitude-group 6·3 to 6·7 ;

and similarly for the subsequent numbers given in the magnitude column.

Column VIII. gives the mean densities for the different magnitude-groups, excluding the stars in the equatorial zone of the galaxy, which are used in forming Column V.

TABLE II.

Galactic Latitude.

Magnitude.	I. −90° to −70°.	II. −70° to −50°.	III. −50° to −30°.	IV. −30° to −10°.	V. −10° to +10.	VI. +10° to +30°.	VII. +30° to +43½°.	VIII. Excluding the Galaxy.
To 6·2	·043	·053	·050	·077	·101	·066	·030	·059
6·5	·053	·062	·056	·063	·068	·046	·024	·056
7·0	·135	·125	·140	·176	·180	·149	·145	·153
7·5	·244	·268	·292	·352	·487	·353	·284	·312
8·0	·619	·634	·661	·884	1·346	·887	·679	·743
8·5	·917	1·023	1·219	1·869	3·035	1·727	1·386	1·431
9·0	1·489	2·107	2·981	5·116	9·232	4·343	2·865	3·500
9·5	1·618	2·592	4·249	9·464	19·512	7·995	4·689	5·771
10·0	2·593	3 412	5·058	11·354	29·808	15·503	6 280	7·997
Sums	7·711	10·276	14·706	29·355	63·769	31·069	16·382	
Sums to Mag. 9·2	3·500	4·272	5·399	8·537	14·449	7·571	5·413	
B.D.*	3·14	3·21	3·71	6·07	8·17	5·32		

We recognise here the ring of lucid stars lying nearly in the plane of the galaxy to which Gould and others have drawn attention. It will be remarked that the stars in magnitude-groups 6·5 and 7·0 are much more uniformly distributed than are the brighter stars, and that we must come down to magnitude-group 8·0 before we get as great a relative increase in density between the polar and equatorial zones of the galaxy as we find in the group of lucid stars.

The C.P.D. is not sufficiently extended in galactic longitude in this region to enable us to determine from it with accuracy the deviation (if any) of the ring of bright stars from the plane of the galaxy.

In studying the structure of our universe it is important to note the nearly uniform distribution of the stars of medium brightness.

The falling off in relative density after the magnitude 9·2 is passed, to which attention has been already drawn, as shown in Table I., is apparent throughout the zones of galactic latitude; equally in the polar zone (I.), the equatorial zone (V.), and in the mean densities, excluding the equatorial zone (VIII.). This

* Seeliger's discussion of the Bonn *Durchmusterung* (see Newcomb, *The Stars*, page 249).

must not, however, be taken as evidence of any thinning out of the stars of the fainter magnitudes here considered, but rather of the fact that we have passed the limit of magnitude to which the survey is complete.

The "Sums" show the aggregate densities in the different zones of galactic latitude for the stars down to mag. 10·2.

The "Sums to mag. 9·2" show the same down to the limit of magnitude to which the survey is assumed to be complete. The latter series is fairly comparable with the Bonn *Durchmusterung*, the results of which, as deduced by Seeliger, are given in the table. We recognise the greater relative aggregation of stars in the neighbourhood of the galaxy which appears in the photographic, as compared with the visual, survey, to which Kapteyn has drawn attention. Whether this arises from the greater efficiency of the photographic plate in the more crowded regions, or from the greater actinic activity of stars near the galaxy, appears as yet to be an open question. The C.P.D., however, agrees with the B.D. in assigning an ellipsoidal form to our universe of stars to the magnitude here considered, although pointing to a greater ellipticity of the ellipsoid, by reason of the greater relative extension towards the plane of the galactic equator.

Table III. gives the ratios of increase for one magnitude (as defined above for the corresponding quantities in Table I.) for the stars contained in the equatorial zone of the galaxy (I.), and for the residuum of stars, excluding this zone (II.). The latter series is comparable with the results obtained by Newcomb from his discussion of the star densities in certain non-galactic regions of the Cordoba DM., after the application of systematic corrections to the registered magnitudes to reduce them to the Harvard photometric scale (*Astronomical Journal*, No. 507). These are added in column III.

Table III.

Magnitude.	I. (Galaxy.)	II. (Non-galactic.)	III. (Non-galactic.)
6·5	2·80	3·80	
			3·44
7·0	4·26	5·43	
			2·39
7·5	5·74	4·68	
			2·40
8·0	6·81	5·20	
			3·48
8·5	5·72	4·33	
			2·42
9·0	7·67	5·16	
			2·55
9·5	5·52	3·70	
10·0	3·53	2·77	

The relatively large values obtained here, as well as in Table I., for the C.P.D., as compared with Newcomb's results, are remarkable, pointing to a systematic difference in the scale of magnitudes respectively adopted.

The systematic corrections to the photographic magnitudes of the C.P.D. to reduce them to the visual magnitudes of Gould's Zone Catalogue, which are given by Kapteyn (*Annals of the Cape Observatory*, vol. v. p. 32), exhibit a similar discrepancy between the scales of the photographic and visual systems to that which is here disclosed. It will be remembered that Seeliger, in his discussion of the B.D. results, referred to above, found the value of the ratio in question to lie between 3 and 4 for the brighter stars. Seeliger's researches show that the ratio differs in different parts of the sky, and becomes exceptionally large in the galaxy itself, agreeing in this respect with the results for the relative values of the ratios given in columns I. and II. of Table III.

The publication of the authors' further discussion of the system of photographic magnitudes of the C.P.D. will be awaited with interest.

Note on the Principle of the Arithmetic Mean.

By H. C. Plummer, M.A.

1. In this note it is proposed to make a brief comparative study of certain lines of argument which are connected with the establishment of the arithmetic mean of a series of direct observations of a single quantity as the most plausible value to adopt. It has been suggested (by Encke, for example) that this position has been assigned to the arithmetic mean by experience, and even that the principle has an axiomatic character. This does not seem by any means to be the case. The arithmetic mean has always been, and probably always will be, adopted because it is by far the easiest function of the observations to calculate.* Also, although demonstrations of the principle may be wanting in rigour, its position has not been assailed by a rival more formidable in this respect or more acceptable on general grounds. If it be granted that positive and negative errors are equally likely to the same amount, it is obvious—and the formal remark has been made by Ellis†—that the arithmetic mean coincides with the true value in the limit when the number of observations is infinite. For if a is the true value, $x_1, x_2, \ldots$ the n observed quantities, and $e_1, e_2, \ldots$ the errors, then

$$\Sigma(x-a) = \Sigma e,$$

so that

$$a = \frac{\Sigma x}{n} - \frac{\Sigma e}{n} = \frac{\Sigma x}{n}.$$

* With the exception of the Median, advocated by Edgeworth (*Camb. Phil. Trans.*, 1889, and *Phil. Mag.*, 1887), and by Estienne in his *Etude sur les erreurs d'observation*, Paris, 1890.

† *Camb. Phil. Trans.* vol. viii. p. 205 (1844).

But the axiom assumed cannot be supposed to hold generally. To consider a very simple example, let observations be made of the position of a point relatively to a scale. If the graduations are equidistant, the axiom will probably hold. If the scale is unequally divided, the axiom seems decidedly improbable. A proof of the principle of the arithmetic mean in the general sense seems therefore to be out of the question. It appears more philosophical to regard the hypotheses on which it has been sought to establish the principle not so much in the nature of axioms as of definitions in the simplest form of the properties which the observations must possess if the principle is to hold.

2. Two preliminary hypotheses which call for little remark may be given. The first is

Hypothesis I.—The function to be adopted is a symmetrical function of the observed quantities.

This must be admitted *a priori*, and must be allowed to stand *a posteriori* if the observations actually made are considered equally plausible. The second is

Hypothesis II.—The function is homogeneous and of the first degree.

This is necessary if the observations are to be allowed the first element of generality. For otherwise the result would not be independent of the unit of measurement.

3. Any function which satisfies these hypotheses, and which becomes identical with the common value of the observed quantities when these coincide, may be called *a* mean value. By the use of Taylor's Theorem De Morgan * expanded such a function in terms of an arbitrarily chosen magnitude and its deviations from the observed quantities. The terms of the first order reduce to the arithmetic mean of the observations, and he thus showed that every mean value consists of the arithmetic mean together with an aggregate of terms with regard to which we have no *a priori* knowledge. Ferrero † has followed the same order of thought, but has replaced the arbitrary magnitude by the arithmetic mean. He then pointed out that the coefficient of terms of the second order in the deviations in general bears a ratio to the reciprocal of n, the number of observations, which does not become infinite with n. He therefore concluded that every mean value approximates more closely to the arithmetic mean as the number of observations is increased and their accordance is improved.

4. A third hypothesis may now be added to the preceding. This is

Hypothesis III.—If all the measures are given any increment a, the most probable value of the quantity sought receives the same increment a.

In other words, the result is independent of the origin of

* *Camb. Phil. Trans.* vol. x. p. 416 (1864).

† *Esposizione del Metodo dei Minimi Quadrati*, p. 11 (1876).

measurement. If the most probable value be the function ϕ of the observed quantities $x_1, x_2, \ldots x_n$ the analytical expression of the third hypothesis is obtained at once by making the increment a infinitesimal in this form:

$$\frac{\partial\phi}{\partial x_1}+\frac{\partial\phi}{\partial x_2}+\cdots+\frac{\partial\phi}{\partial x_n}=1 \qquad \ldots \qquad \ldots \qquad (1)$$

of which the integral is

$$\phi=\frac{1}{n}(x_1+x_2+\ldots+x_n)+\mathrm{F}(x_2-x_1, x_3-x_1, \ldots, x_n-x_1) \quad (2)$$
$$=\mathrm{M}+\mathrm{F}$$

where M is the arithmetic mean and F is a function of the differences of the observed quantities which satisfies hypotheses I and II. It must be noticed that there is no necessity to suppose that F is a rational and integral function. Otherwise F would vanish by virtue of hypothesis II. This point will be examined further in § 8.

5. The third hypothesis might be replaced by one expressed in a totally different form and yet equivalent to it—

Hypothesis III (a).—The law of facility of an error e can be expressed by a function of e.

Let $\psi(e)$ be the function to which the probability of an error e is proportional. If, then, z is the most probable result, the product

$$\psi(z-x_1)\,\psi(z-x_2)\ldots\psi(z-x_n)$$

is a maximum. Therefore

$$\frac{\psi'(z-x_1)}{\psi(z-x_1)}+\frac{\psi'(z-x_2)}{\psi(z-x_2)}+\cdots+\frac{\psi'(z-x_n)}{\psi(z-x_n)}=0.$$

Now the form of this equation which z must satisfy shows immediately that z satisfies the conditions of hypothesis III. Hypotheses III and III (a) are therefore equivalent, and the latter imposes on z the form assigned to ϕ in (2). The geometric mean of the observed quantities, for example, is inconsistent with any law of facility. This has been remarked by Bertrand,* who deduced equation (1) from the fact that the functional determinant of

$$\phi-x_1, \phi-x_2, \ldots, \phi-x_n$$

vanishes. This argument seems rather to obscure the real simplicity of the result.

6. Bertrand † has also pointed out that the adoption of precise and independent definitions of the terms *precision* and *weight* suffices to restrict the form of the facility function. Let

* *Calcul des Probabilités*, p. 182 (1889).
† *Loc. cit.* p. 210.

the functions for two different series of observations be $\psi_1(e)$ and $\psi_2(e)$. Let the ratios of the precisions be h, and the ratio of the weights k, in the two series. The definitions of the terms are such as to imply that the ratios

$$\frac{\psi_1(he)}{\psi_2(e)} \text{ and } \frac{\psi_1(e)^k}{\psi_2(e)}$$

are constant. Accordingly

$$\psi_1(he) = G \cdot \psi_1(e)^k$$

where G is independent of e. The solution of this functional equation is

$$\psi_1(e) = C \quad \exp.(-ae^\mu)$$

wherein

$$k = h^\mu, \quad G = C^{1-k}$$

When $\mu = 2$ the solution gives the orthodox law of facility for which $k = h^2$. But any even values of μ would be equally consistent with definitions of precision and weight based respectively on the idea of equal probability of proportional errors in two systems of observations, and on the idea of the equivalence of a measure in one system to several identical measures in another.

7. It is not intended in this note to consider the form of the facility function as such. But with the general form found in § 6, the most probable value of the quantity sought from a series of observations must make

$$(z-x_1)^\mu + (z-x_2)^\mu + \ldots + (z-x_n)^\mu$$

a minimum, so that

$$(z-x_1)^{\mu-1} + (z-x_2)^{\mu-1} + \ldots + (z-x_n)^{\mu-1} = 0.$$

This equation, which clearly, since $\mu-1$ is odd, has one and only one real solution, may be written in the form

$$(s_0, s_1, \ldots, s_{\mu-1})(z, -1)^{\mu-1} = 0,$$

where

$$s_r = x_1^r + x_2^r + \ldots + x_n^r.$$

In order to obtain a concrete example, let the case be considered in which $\mu = 4$. In the equation

$$(s_0, s_1, s_2, s_3)(z, -1)^3$$

let the roots be diminished by $M = s_1/n$. The result is the transformed equation

$$s_0 y^3 + 3y\left(s_2 - \frac{s_1^2}{s_0}\right) - s_3 + \frac{3s_1 s_2}{s_0} - \frac{2s_1^3}{s_0^2} = 0.$$

The solution is

$$y = a^{\frac{1}{3}} + \beta^{\frac{1}{3}},$$

where a, β are the roots of the quadratic

$$x^2 - \left[\frac{s_3}{s_0} - \frac{3s_1s_2}{s_0^2} + \frac{2s_1^3}{s_0^3}\right]x + \left[\frac{s_1^2}{s_0} - s_2\right]^3 = 0.$$

Hence

$$z = \mathrm{M} + a^{\frac{1}{3}} + \beta^{\frac{1}{3}}$$

is a function which might be considered the most plausible to adopt as the value of the quantity measured, in the sense that it satisfies the hypotheses so far introduced and is not inherently impossible.

8. The function just found, although not an impossible one nor without a certain interest, has not been constructed for its own sake, but in order to prove by an actual example that hypotheses II and III do not suffice to limit the function of the observed quantities to the arithmetic mean. This is in direct contradiction to the conclusion of Ferrero,* who attempted to prove that the principle of the arithmetic mean was a necessary consequence of these postulates. It has already been noticed in § 4 that F cannot possess a rational and integral form. This suggests that there must be some tacit assumption underlying Ferrero's proof. It is introduced by the expansion of the function in terms of the arithmetic mean and its deviations from the observed quantities. The want of rigour in the proof is due to the assumption that the use of Taylor's Theorem is legitimate. Apparently the existence of functions which cannot be expanded by Taylor's Theorem has been ignored.

9. It is therefore necessary to seek another condition which must be satisfied by the most probable value of the observed quantity. The simplest one seems to be

Hypothesis IV.—The independent measures must be combined in such a way that an error which may exist in one of the measures, as x_1, shall produce the same error in the "value adopted as the most probable" as would be produced by the same error in x_2, x_3 or x_n.

The axiomatic character of this hypothesis does not seem to be obvious, but as an expression of a necessary property of the most probable value it is at least interesting. The condition is at once expressed in analytical form by making the error in $x_1, x_2, \ldots$ or x_n infinitesimal. The equations immediately obtained are

$$\frac{\partial \phi}{\partial x_1} = \frac{\partial \phi}{\partial x_2} = \frac{\partial \phi}{\partial x_3} = \ldots = \frac{\partial \phi}{\partial x_n} \quad \ldots \quad \ldots \quad (3)$$

* *Loc. cit.* p. 40.

The first equality gives at once

$$\phi = f(x_1 + x_2).$$

Hence

$$\frac{\partial\phi}{\partial x_1} = \frac{\partial\phi}{\partial x_2} = \frac{\partial\phi}{\partial(x_1 + x_2)} = \frac{\partial\phi}{\partial x_3},$$

and consequently

$$\phi = f(x_1 + x_2 + x_3).$$

Proceeding thus we obtain finally

$$\begin{aligned}\phi &= f(x_1 + x_2 + x_3 + \ldots + x_n) \\ &= \phi(\mathrm{M}) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)\end{aligned}$$

and if ϕ is a function of invariable form, that form seems to follow most simply by supposing the observed quantities to coincide with a single value a. For then clearly

$$\phi(a) = a$$

and

$$\phi = \phi(\mathrm{M}) = \mathrm{M} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

Thus the principle of the arithmetic mean follows from the hypothesis.

10. Hypothesis IV is due to Stone,* in whose conception its truth seems to have possessed an intuitive character. His method of deducing the equation (4) seems needlessly complicated, and withal not altogether free from objection, as it involved the ex-expansion of the function by Taylor's Theorem. The completion of the proof of the principle in view was effected by the method of induction from the case when $n=2$. In this case, as Glaisher† has pointed out, the truth follows from the theory, though it may be remarked that the "theory" depends on the unproved assumption expressed in Hypothesis III (a). The use of the method of induction seems no more satisfactory and much less simple than the line of argument adopted in deducing equation (5) from equation (4).

11. The last proof of the principle of the arithmetic mean which will be noticed here is the one which is due to Schiaparelli.‡ As a basis of this proof he adopted Hypotheses II, III, and IV. The combination of equations (1) and (3) with the analytical expression of the second hypothesis by means of Euler's Theorem leads at once to the desired result. Schiaparelli arrived at the fourth hypothesis quite independently. It is interesting to notice that these two writers were led to adopt it from quite

* *Monthly Notices*, vol. xxxiii. p. 570 (1873).
† *Memoirs of the R.A.S.* vol. xxxix. p. 92 (1872).
‡ *Astr. Nachr.* Nr. 2068 (1875).

different points of view. As has been said, Stone attributed to the condition an *a priori* character. On the other hand, it appears from a later note * that Schiaparelli started with the necessary differential equations and then sought to give them as it were a physical interpretation. Thus Schiaparelli's proof appears frankly artificial, and confirms a remark, made earlier in the present note, that it may be wiser to regard the hypotheses as defining the properties which the observations must possess rather than as axioms on which a rigorous proof of the principle of the arithmetic mean can be founded.

12. I cannot conclude this brief note without expressing my indebtedness to that section of Emanuel Czuber's "Theorie der Beobachtungsfehler" which treats of the principle of the arithmetic mean, both for references and for a connected account of the main lines of earlier discussions of the subject.

University Observatory, Oxford:
1902 May 28.

Experimental Reduction of Photographs of Eros for the Determination of the Solar Parallax. Second Paper: *Combination of Results from Mount Hamilton, Minneapolis and Cambridge.* Arthur R. Hinks, M.A.

1. In a recent paper (*Monthly Notices*, 1901 November, vol. lxii. p. 22) I attempted to develop a somewhat new method of comparing with an ephemeris positions of a planet derived from measures upon photographs. Briefly the method was this: Separate heliocentric ephemerides of the planet and of the Earth are expressed in rectangular coordinates referred to a mean ecliptic and equinox, the unit being naturally the mean distance of the Sun from the Earth. From these two simple ephemerides (which arise in the process of computing the usual apparent place ephemeris) it is comparatively easy to compute the position of the planet upon a "standard" plate of given centre; the only transformation of coordinates which is not a mere addition, viz. the change from axes in and perpendicular to the ecliptic to axes in and perpendicular to the plate, is expressed in terms of direction cosines and performed with considerable ease on an arithmometer. In fact, the method offers the advantage that almost throughout the coordinates are rectangular, the transformations linear, and the numerical operations are consequently such as can be performed much more readily with a calculating machine than with logarithms.

2. For a trial of the method I measured and reduced fifty-two exposures of *Eros* made at Cambridge on 1900 November 9 and

* *Astr. Nachr.* Nr. 2097 (1876).

10. All the details of the reductions to standard, and of the method then used of comparing with the ephemeris computed for me by Professor E. Millosevich, will be found in the first paper. We need mention here only one point. In order satisfactorily to represent the observations it was necessary to correct the ephemeris by terms varying directly with the time. At the same hour angles on two successive nights the differences, computed minus observed position of the planet, were not the same. It seemed that the ephemeris would not represent the motion of the planet for so long a period as twenty-four hours, and in that case it would be clearly impossible to determine the parallax by the diurnal method from the results of any number of single disconnected nights. Parallactic shift and progressive error of the ephemeris are hopelessly interwoven, and nothing can be done unless we have observations at the same hour angles, and therefore with the same parallax factors, on adjacent nights. Then only can the progressive error of the ephemeris be separated from the parallax and empirically eliminated before proceeding to the solution of the equations of condition. It is clear, however, that this procedure breaks down unless the series of observations is fairly continuous—which in the winter of 1900–01 was by no means the case—and that in general a large part of the work of any observatory must be excluded from a parallax discussion of the results of that observatory alone.

The difficulty might be overcome by making a preliminary solution of all the results from all the co-operating observatories, deducing therefrom a series of corrections to the tabular place of the planet, and basing upon these a new ephemeris. This would represent the apparent motion of the planet very accurately. But Sir David Gill remarks, in his discussion of the heliometer observations of *Victoria*, that the resulting ephemeris must be looked upon rather as an interpolation formula than as the equivalent of a genuine orbit that will continue to represent the planet's motion for any length of time; wherefore he took his tabular places from the second ephemeris of *Victoria* and his tabular distances from the first; and there is the further disadvantage that a complete preliminary discussion for tabular errors of the ephemeris would delay for an indefinite time the deduction of any satisfactory value of the parallax; the mass of observations is too large and too heterogeneous to be dealt with in this laborious way.

But we have an obvious alternative. In every case of a pair of nearly simultaneous observations of *Eros* made at stations far apart, the tabular place of *Eros*, be it good or bad, is practically eliminated when it is a question only of finding the parallax, and not of correcting the ephemeris, and it seems that at first it will be better policy to aim at combining directly the observations in groups extending over so short a time that the errors of the ephemeris have no time to develop, rather than to work for a complete general reduction of the whole material at one

sweep. The photographs of *Eros* number so many thousands that we may expect to find a great many cases where the observations may be separated in this way into small groups. The aim of this paper is to apply to two or three such cases the method of reduction which was developed in the previous paper.

3. The publication in the Paris circulars of a detailed statement of what each observatory has achieved makes it very easy to select good examples of pairs of nearly simultaneous observations at stations far apart. I found that at three observatories in the United States—Lick, Minneapolis, and Northfield—they had plates taken very nearly at the same time as some of those of 1900 November 9 and 10 which I was reducing by the diurnal method. A request for early measures of these plates brought from the directors of the three observatories a very kind and ready response. The measurement of the photographs made at Mount Hamilton with the Crossley reflector had been undertaken by the Columbia University Observatory, New York; and at the request of Professor W. W. Campbell Professor J. K. Rees pushed forward the measurement of eight exposures of the planet and of selected comparison stars, and sent me the measures. Professor F. P. Leavenworth measured seven exposures made at the Observatory of the University of Minnesota, and Professor H. C. Wilson, Director of the Goodsell Observatory, replied that the plate I wanted had been spoiled by passing clouds, and was probably not worth measuring, but promised measures of any other plates that might be useful. To all my sincere thanks are due for the kindness with which they undertook to place at my disposal the material for this second experiment.

4. Meanwhile M. Loewy, President of the *Eros* Commission of the Paris International Conference of 1900, had undertaken to superintend the computation of an eight-figure ephemeris of *Eros* based upon the latest orbit of Professor Millosevich. It was to give, as usual, apparent R.A. and Decl. of the planet, but at my request he promised to print also the separate heliocentric ephemerides of the planet and of the Earth, expressed in rectangular coordinates referred to the mean ecliptic and equinox of 1900·0, which arise in the course of computation of the other ephemeris, and which are of the form most convenient for the method I am using. These ephemerides have recently appeared in the ninth *Paris circular*, and I must not fail to acknowledge my obligations to M. Loewy for the kindness with which he has taken much trouble to forward the trial of a plan very different from that which he himself prefers.

5. We must now reproduce briefly the expressions for the computed place of the planet upon our standard plate, whose centre is given.

Take three rectangular axes, with centre of Sun as origin, directed towards the mean equinox for 1900·0, the point in the ecliptic whose longitude is 90°, and the pole of the ecliptic. At an epoch T, when light left it, the coordinates of the planet on

this system are U, V, W; at the epoch T+ΔT when that light reached the Earth the coordinates of the Earth are f, g, h. These six quantities, U, V, W; f, g, h, are found by interpolation in the heliocentric ephemerides referred to above; and U−f, V−g, W−h are the coordinates of the planet at T as seen from the centre of the Earth at T + ΔT.

Suppose now that we take a new system of rectangular axes through the centre of the Earth, parallel to the two axes of rectangular coordinates on the standard plate and to the normal to the plate; and let l_1, m_1, n_1, &c., be the direction cosines of the new axes with respect to the old. Then the coordinates of the planet with respect to these new axes are

$$\begin{aligned} \mathrm{L} &= l_1(\mathrm{U}-f)+ l_2(\mathrm{V}-g)+ l_3(\mathrm{W}-h) \\ \mathrm{M} &= m_1(\mathrm{U}-f)+m_2(\mathrm{V}-g)+m_3(\mathrm{W}-h) \\ \mathrm{N} &= n_1(\mathrm{U}-f)+n_2(\mathrm{V}-g)+ n_3(\mathrm{W}-h) \end{aligned}$$

and, omitting for the moment the parallax terms, the coordinates of the planet on the standard plate are $\xi_0 = \mathrm{L}/\mathrm{N}$, $\eta_0 = \mathrm{M}/\mathrm{N}$.

The procedure adopted in the first paper was therefore as follows: Compute for each exposure T, T+ΔT, and the corresponding interpolation coefficients, and thence the coordinates U, V, W; f, g, h.

Compute once for all the nine direction cosines; thence for each exposure the values of L, M, N; and thence ξ_0, η_0.

Now all this involved a good deal of multiplication by direction cosines. Performed on the arithmometer the work was heavy, but I do not think heavier than in the alternative process of interpolating in the ephemeris for App. R.A. and Decl., and thence transforming to rectangular coordinates on the standard plate. The interpolation in the heliocentric ephemerides is much less troublesome; but without an arithmometer the labour of the whole process would have been prohibitive.

6. It now seems to me that when we have to deal with a large number of exposures with approximately the same centering, or which have been reduced to the same standard plate, an altogether better plan is to start by constructing a "plate ephemeris" for that particular centre.

For the standard plate of 1900 Nov. 9 and 10 the coordinates of whose centre are α $1^h\,57^m\,8^s$ $\delta+54°\,22'$ I have made a plate ephemeris as follows:—

f, g, h are the heliocentric ecliptic coordinates of the Earth for successive Berlin midnights taken directly from the ephemeris (*Paris circular*, No. 9, p. 194, where $f=-\mathrm{X}$, $g=-\mathrm{Y}$, $h=-\mathrm{Z}$).

U, V, W are the heliocentric ecliptic coordinates of *Eros*, interpolated from the ephemeris of the planet, for successive epochs—Berlin midnight minus the aberration time.

The values of the direction cosines are :—

l_1 −·48912876	m_1 −·70890040	n_1 +·50814690
l_2 +·80015971	m_2 −·13284009	n_2 +·58489137
l_3 −·34712745	m_3 +·69268589	n_3 +·63220945

Thence we find for each Berlin midnight the values of L, M, N, and thence of ξ_0, η_0.

We have now an ephemeris which gives the standard coordinates on our plate (except for the parallax displacements which have not yet been put in) of the places of the planet at the times light left it as seen from the Earth at successive Berlin midnights when the light arrived. If we now interpolate in this ephemeris for the mean epochs of our exposures, and calculate the parallax displacements exactly as before (*Monthly Notices*, lxii. p. 30) we have what we want, the computed standard coordinates of the planet at the times the light left it, as seen from our position on the Earth at the times the light reached it.

Plate Ephemeris of Eros for Plate Centre, $1^h\ 57^m\ 8^s + 54°\ 22'\ 0''$ (1900-0).

1900.	ξ_0.	η_0.
Nov. 7	+·01472591	−·00060344
8	+·00947016	·00030762
9	+·00422788	·00027106
10	−·00098974	·00049666
11	−·00617220	·00098664
12	−·01130788	−·00174276

There is here a considerable saving of labour. We save the greater part of the computation of the epoch T and its interpolation coefficients; of the interpolations for the six quantities U, V, W; f, g, h; of the long multiplications by direction cosines, and of the subsequent divisions by N; for these operations have to be performed for six epochs only instead of perhaps a hundred. Eventually we have to interpolate for two quantities, standard coordinates instead of App. R.A.'s and Decl.; and the labour of constructing the plate ephemeris to start with is much less than that of turning a large number of R.A.'s and Decls. into standard coordinates, especially when the former can be done on the arithmometer. Finally we are spared the labour of computing and taking out the correction to the planet's place for the aberration of light, which has in the ordinary course been automatically but improperly introduced by the process of reduction (see Mr. Cowell's paper in *The Observatory*, 1900 December, and mine, *Monthly Notices*, lxii. p. 29).

7. The reduction to standard of the Cambridge exposures

has been done in two steps. An exposure near the meridian on Nov. 10 was selected as a "zero exposure," and all the exposures of the series A (guiding on the stars) were first reduced to this by the six constant formulæ (Turner's), with constants derived from the measures of fourteen comparison stars nearly equal to the planet in magnitude. All were then reduced from zero to standard by the constants derived from measures of thirteen meridian standard stars on the zero plate.

In the present reductions I have taken the mean of all the plates of series A reduced to zero as a new zero plate, with the purpose of avoiding systematic errors in the constants of reduction to zero which might arise from accidental errors in the old single zero plate. We will call this the mean zero plate.

The constants of the reduction from mean zero to standard were derived from the seven stars on the plate which have been observed by a great number of observatories as *étoiles de repère* for the *Eros* plates (*Paris circulars* 8 and 9). The number is small for two reasons: first, that the Paris list was selected for the astrographic plates of 2° square, and a number of stars lie just outside the edge of my plates, which cover only $1\frac{1}{2}$° square; second, that two of the Paris stars are not available, one because it is so bright that adjacent images interfere with one another, the other because it is unfortunately the variable *U Persei*, which was faint at the time that *Eros* passed near it. By bad luck these two stars were especially wanted to give a good determination of the scale value in ξ; and I am not satisfied that a part of the apparent increase of the tabular error of the ephemeris with the time may not be due to erroneous scale value. This would be fatal to a determination of the parallax by the diurnal method, but is easily seen to have no sensible effect on the present reductions.

8. I have chosen deliberately to retain the six constants in the reduction, that is, to admit a possible difference of scale value in the directions of the two axes of coordinates, rather than to calculate and apply the whole or the unsymmetrical part of the differential refraction, and thus reduce the constants required by theory to four. The argument of those who contend for the latter procedure appears to be that when the unsymmetrical part of the refraction is removed all the remaining necessary corrections ought to be, and therefore are, symmetrical. In reply to this I would urge that in actual fact they frequently are not. Time after time I have found that the asymmetry of the six constants found by the direct reduction, according to Turner, does not correspond at all with the asymmetry produced by the differential refraction. Pending the collection of more material for an examination of this point, one may do either of two things:—use six constants and secure the best fit possible between two plates to be compared, or use four and be satisfied with a fit not the best possible, but the best consistent with the hypothesis of symmetry. I think that there can be no doubt that the former

is the more prudent course, and am not at present prepared to admit that the use of the six constants involves any loss of weight or of rigour.

9. The following are the details of the photographs used in the present discussion.

Lick. Crossley Reflector. Aperture 3 ft.; focal l. 17 ft. 6 in.

Plate No.	Epoch of Mid. Exp.	h	m	s	Duration of Exp. s	No. of Comp. Stars.
461 (1)	G.M.T. Nov. 9	15	18	15	10	6
(5)		15	19	50	20	6
462 (3)		15	24	5	10	6
472 (1)	Nov. 10	14	16	15	10	7
(3)		14	16	57·5	15	7
480 (1)		14	50	15	10	7
(3)		14	50	57·5	15	7

Minneapolis. Refractor. Aperture 10½ in.; focal l. 11 ft. 3 in.

		h	m	s	m	s	
1	Nov. 10	13	52	6	2	0	14
3		14	3	49	3	30	14

Cambridge. Refractor. Aperture 12½ in.; focal l. 19 ft. 2 in.

		h	m	s	m	
246	Nov. 9	15	36	1	3	14
247		15	39	51	2	,,
250		16	35	21	3	,,
251		16	38	11	2	,,
274	Nov. 10	12	39	29	3	,,
275		12	42	24	2	,,
278		13	37	24	3	,,
279		13	40	19	2	,,
282		14	40	54	3	,,
283		14	44	24	2	,,

After a preliminary reduction of the Lick and Minneapolis measures to the scale of the Cambridge plates the equations of condition were formed to reduce each exposure to the Cambridge mean zero plate, the six constants were found for each exposure, and the measures of the planet reduced to Cambridge mean zero, and thence to standard by the constants derived from the reduction of the mean zero plate to standard with the new places of the *étoiles de repère* from the Paris circulars. These standard places of the planet are next expressed in parts of the radius of projection, and thenceforward the unit to be employed

is 1×10^{-7} of the radius. It has been assumed for the present that the weight of each plate is the same.

Since we are concerned more with methods than with numerical results, it is unnecessary to print the details of the measures and reductions.

10. Neither is it necessary to follow in detail the steps required to form the equations of condition. The tabular places of the planet were interpolated from the "plate ephemeris"; the parallax factors were found as in the previous paper (*Monthly Notices*, vol. lxii. p. 30); the tabular places were corrected for parallax with an assumed value of the solar parallax, and compared with the observed places. Finally means were taken of pairs of observations close together, which are then treated as one observation.

If $\Delta\pi$ is the correction required to the assumed value of the solar parallax, $\Delta\xi_0$ and $\Delta\eta_0$ the corrections to the plate ephemeris supposed constant for the two short periods under discussion, we have the following equations of condition :—

Nov. 9.					Residuals.
Camb. 246,7	$+1{\cdot}56\,\Delta\pi$	$-1\,\Delta\xi_0$	$0\,\Delta\eta_0$	$-90 = 0$	-3
	$+0{\cdot}86$	0	-1	$+5$	$+7$
250,1	$+1{\cdot}62$	-1	0	-80	$+7$
	$+1{\cdot}19$	0	-1	-16	-14
Lick 461 (1, 5)	$-1{\cdot}68$	-1	0	-85	-1
	$-0{\cdot}11$	0	-1	$+5$	$+6$
462 (3)	$-1{\cdot}65$	-1	0	-87	-2
	$-0{\cdot}15$	0	-1	$+2$	$+2$

The last two equations, being dependent upon one exposure only, have been given half weight.

Nov. 10.					Residuals.
Camb. 274,5	$+0{\cdot}84\,\Delta\pi$	$-1\,\Delta\xi_0$	$0\,\Delta\eta_0$	$-72 = 0$	$+1$
	$+0{\cdot}08$	0	-1	-27	$+3$
278,9	$+1{\cdot}17$	-1	0	-69	$+3$
	$+0{\cdot}29$	0	-1	-28	$+2$
282,3	$+1{\cdot}44$	-1	0	-73	-2
	$+0{\cdot}59$	0	-1	-27	$+2$
Lick 472 (1, 3)	$-1{\cdot}96$	-1	0	-77	$+5$
	$+0{\cdot}27$	0	-1	-31	-1
480 (1, 3)	$-1{\cdot}81$	-1	0	-83	-1
	$+0{\cdot}04$	0	-1	-31	0
Minn. 1, 3	$-1{\cdot}30$	-1	0	-86	-6
	$-0{\cdot}01$	0	-1	-36	-5

The normal equations derived from these are :—

Nov. 9.	$+11{\cdot}43\,\Delta\pi$	$-0{\cdot}67\,\Delta\xi_0$	$-1{\cdot}86\,\Delta\eta_0$	$-\ 70=0$
	$-\ 0{\cdot}67\,\Delta\pi$	$+3{\cdot}50\,\Delta\xi_0$	$0{\cdot}00\,\Delta\eta_0$	$+299=0$
	$-\ 1{\cdot}86\,\Delta\pi$	$0{\cdot}00\,\Delta\xi_0$	$+3{\cdot}50\,\Delta\eta_0$	$+\ \ 5=0$
Nov. 10.	$+13{\cdot}47\,\Delta\pi$	$+1{\cdot}62\,\Delta\xi_0$	$-1{\cdot}26\,\Delta\eta_0$	$+131=0$
	$+\ 1{\cdot}62\,\Delta\pi$	$+6{\cdot}00\,\Delta\xi_0$	$0{\cdot}00\,\Delta\eta_0$	$+460=0$
	$-\ 1{\cdot}26\,\Delta\pi$	$0{\cdot}00\,\Delta\xi_0$	$+6{\cdot}00\,\Delta\eta_0$	$+180=0$

Eliminating successively $\Delta\xi_0$ and $\Delta\eta_0$ from each of these sets we obtain two equations for $\Delta\pi$.

From Nov. 9.	$+10{\cdot}31\,\Delta\pi=+10$
Nov. 10.	$+12{\cdot}77\,\Delta\pi=-45.$

Assuming that the p.e. of an equation of weight unity is the same on each night we add these together, and find

$$\Delta\pi=-1{\cdot}5 \qquad =-0''{\cdot}031.$$

If we carry out the solutions separately for each day we obtain

For November	9	$\Delta\xi_0=-85$	$\Delta\eta_0=-\ 1$	$\Delta\pi=+0{\cdot}97$
	10	$\Delta\xi_0=-76$	$\Delta\eta_0=-31$	$\Delta\pi=-3{\cdot}52$

and substituting back in the equations of condition we obtain the residuals given in the last column.

From these we find

P.E. of one equation of weight unity

November	9	$\pm5{\cdot}6$	$=\ \pm0''{\cdot}11$
	10	$\pm2{\cdot}4$	$=\ \pm0''{\cdot}05$

The great difference between the apparent weights for the two nights is caused almost entirely by the discrepant Cambridge observation in η on November 9 (the fourth equation of condition). On the other hand, perhaps the observations of November 10 are unusually accordant. We may take for the present the p.e. of one equation of weight unity, derived from the mean of a pair of exposures, as about $\pm\,0''{\cdot}07$; and it is scarcely worth while to examine minutely the probable errors of the quantities derived from so few equations.

The differences between the corrections to the tabular places on November 9 and 10 come out rather large, and it is not possible with this small amount of material to say how far they are real. But they emphasise the necessity for dividing the equations, as has been done here, into groups derived from observations nearly simultaneous.

I have refrained from giving the assumed value of the parallax to which these observations give the above correction, because no good purpose can be served by publishing preliminary results which have but little weight.

11. In summing up the conclusions which may be drawn from these two experimental reductions of *Eros* photographs I would submit.

(1) That the adopted form of ephemeris in rectangular coordinates has been found convenient, and may be used in future definitive reductions.

(2) That the direct comparison of simultaneous photographs by linear reductions is the most convenient method of dealing with the *Eros* plates. If the same comparison stars are used, it is not required that their meridian places should all be known; if the meridian places of the comparatively few standard stars are not quite accurate, the resulting parallax is scarcely affected; if the ephemeris needs correction by terms varying with the time, practically no harm is done. In fact, by working in this way we can find the parallax by methods which are differential, and do not involve absolute places, except in a secondary degree. The gain is obvious.

(3) The smallness of the probable error of an equation of condition is satisfactory evidence of the value of photographic methods for finding the solar parallax. If the results of a larger series come out as well as those that have been discussed here, that is to say, if the p.e. of an equation of condition derived from the mean of two exposures is about $\pm 0''\cdot07$, we shall not want to discuss the whole of the existing material to obtain a value of the solar parallax with a p.e. $\pm 0''\cdot005$, which is the value Gill finds for the p.e. of his determination from the heliometer observations of *Victoria*, *Iris*, and *Sappho*. It will be a matter of great interest to see whether the photographic observations of *Eros* confirm this result, which has just been adopted by the Nautical Almanacs, or bring out a smaller value, more in accordance with that required by the planetary theory, and by recent determinations of the constant of aberration combined with the velocity of light.

The sooner this can be done the better. I think, therefore, that our next step should be to extend the limits of these reductions so as to include enough material to give us a value of the solar parallax with a p.e. less than $\pm 0''\cdot005$. We propose to measure next all our Cambridge plates between 1900 November 7 and 15 inclusive, and to combine them with as many simultaneous exposures made at other observatories as may be available. To this end I should like to propose to seven or eight observatories spread over as long an arc of longitude as possible that we should agree upon a common list of comparison stars, and measure up all our plates in that period of nine days. If we can concentrate our attention upon this block of the work the measurement is not so formidable a task as to consume a great

many months. Then when the measures are made we might publish or interchange this raw material and proceed to its discussion.

It should be possible thus to settle in two or three years the question whether or not *Eros* is going to give us the same value of the solar parallax as did the three other less happily situated minor planets. That, I take it, is the main point. If it does not, and we have to proceed eventually to the discussion of the whole mass of material, we shall have gained experience and lost no time by concentrating our energies at first upon a few days' plates.

I must add that my sincere thanks are due to the directors of the Lick Observatory, of the Columbia University Observatory, and of the Oxford University Observatory, who have already cordially agreed to enter into this plan.

Cambridge Observatory:
1902 *June* 9.

Reductions of photographs of Swift's Comet (*a* 1899), *taken at the Cambridge Observatory, with a portrait lens.* By L. N. G. Filon, M.A., B.Sc.

1. In the summer of 1899 I was working at the Cambridge Observatory, and I undertook to help Mr. A. R. Hinks in taking some photographic observations of Swift's Comet *a* 1899, which was visible during May and the beginning of June as a telescopic object.

The plates taken then had perforce to remain unmeasured for a long time, as the present measuring machine of Cambridge Observatory was still in course of construction, and it was nearly eighteen months before it was ready for use. Stress of other work, however, and the fact that the machine was urgently needed at the Observatory for the measurement of the Eros parallax plates prevented my attending at the time to the reduction of these observations.

In February last the machine was available, and the plates capable of measurement were then measured and reduced. The results of the reduction are presented in this paper.

The photographs of the comet were taken with a portrait lens, of about 30 inches focal length and 5 inches aperture, stopped down to work at $f/8$. The portrait lens and its camera, for the loan of which I understand the Observatory was indebted to Professor Turner, were fixed to the tube of the Northumberland Equatorial, which was used as a guiding telescope. The camera was placed at the object-glass end of the telescope. An exposing shutter could be opened and shut from the eye end by pulling a string attached for the purpose.

Apart, then, from any intrinsic value which the comet places found from these observations may possess, the reductions appear to present considerable interest as showing what sort of accuracy may be expected from measures of stars upon plates taken with an ordinary portrait lens. I believe that hitherto this method has not been seriously considered as a means of obtaining accurate places of stars. Many observers, who have not at their disposal a large photographic telescope, may, and do, use portrait lenses. It appeared important to find out whether photographs taken in this way would repay the labour of measurement and reduction.

2. Between May 15 and June 14 eighteen plates in all were taken of the comet, the first eight (May 19–May 25) by Mr. Hinks and the last ten (May 25–June 14) by myself. Of these eighteen plates seven were long exposures taken with the stars trailing and varying from 15 to 109 minutes. Of the remaining eleven plates two were taken through breaks in the clouds, and were not considered good enough for measurement; one, a plate taken on June 14, when the comet was fast receding from the Earth and had become very faint indeed, showed no visible image of the comet after two years. Finally one plate was accidentally broken during the measurements. This left seven plates with measurable images, carrying in all twenty-six exposures, varying from one to eight minutes, as follows :—

Plate No.	Date 1899.	Exposure (*a*).	Exposure (*b*).	Exposure (*c*).
		h m s m s	h m s m s	h m s m s
5	May 19	15 48 35 − 50 35	15 51 10½ − ...	15 53 48 − 55 48
7	23	17 34 20 − 39 20	17 41 20 − 46 20	17 47 6 − 54 6
10	26	16 35 55 − 39 55	17 5 2 − 9 2	17 13 0 − 19 0
11	29	18 2 40 − 5 40	18 6 45 − 10 45	18 11 52 − 15 52
14	31	16 10 8 − 14 8	16 19 32 − 23 32	16 24 45 − 30 45
16	June 3	18 27 0 − 32 0	18 33 0 − 41 0	...
17	5	17 38 0 − 43 0	17 44 0 − 49 0	17 50 0 − 58 0

The times given in the above are the Cambridge sidereal times of beginning and end of each exposure. All the above exposures were measured, excepting *b* of plate 5.

3. A very full description of the Cambridge measuring machine and of the method of using it has been given to the Royal Astronomical Society by Mr. Hinks (*Monthly Notices*, 1901 May, vol. lxi. p. 444). There is accordingly no need to repeat here what he has said.

A special difficulty, however, occurred in my case, as two of the plates had no réseau on them, and the Cambridge machine is exclusively adapted for measuring plates with a réseau. The difficulty was solved by placing another plate, provided with a réseau, but otherwise blank, upon the plate to be measured.

The two plates were cemented face to face with a little shellac varnish at the corners. This arrangement was found to work perfectly, the only effect of the thickness of glass introduced being to decrease the effective distance of the plate from the object-glass. Accordingly the focus had to be altered and the scale-value was somewhat different; the latter, however, can be adjusted in the Cambridge machine, so that no inconvenience arose on this score.

Effects of distortion in passing through the plate of glass were calculated and found to be quite negligible to the order of accuracy required for the measurements; and, indeed, these two plates have given results quite as satisfactory as the others. This would tend to confirm that the errors of the gelatine film, which the réseau was originally intended to obviate, are practically nil.

This seemed worth pointing out, because it may occasionally, for some reason or other, be impossible for an observer to have a réseau. Such photographs need not therefore be rejected for measurement.

4. In making the measures two or one settings were made on each réseau line, according as the latter was faint or distinct; generally two settings were made on a star image and three to seven settings on a comet image, according to the degree of faintness or diffuseness. The measures were repeated with

Exposure (*d*).		Exposure (*e*).	Remarks.
h m s — h m s		h m s — m s	
15 57 5 — 16 1 5		16 1 46½ — 2 46½	Clouds for (*b*); no réseau.
...		...	Réseau.
17 21 0 — 25 0		...	No réseau.
18 19 7 — 25 7		...	Réseau.
16 31 55 — 37 55		...	Réseau. Images faint, difficult to measure.
...		...	Réseau.
18 3 0 — 8 0		...	Réseau.

the plate reversed, and the mean of the direct and reversed measures, corrected for run, was taken as the coordinate of image upon the plate.

The settings on any one réseau line and on any one star image were, as a rule, fairly concordant; those on the comet occasionally differed widely.

The divergences of settings in the respective cases of the comet and of a star are illustrated in Table I., taken from the measurements of Plate 14, where the comet images are faint. Only the micrometer head readings are given, as they alone, of course, exhibit differences.

TABLE I.

(*Coordinate y, Pl.* 14.)

	Exposure (*d*). Dir.	Exposure (*d*). Rev.	Exposure (*c*). Dir.	Exposure (*c*). Rev.	Exposure (*b*). Dir.	Exposure (*b*). Rev.	Exposure (*a*). Dir.	Exposure (*a*). Rev.
Comet	120	352	578	850	528	902	234	158
	101	375	585	772	496	938	156	165
	085	369	570	871	502	925	212	186
	120	365	547	850	526	920	245	162
	098	...	550	850	500	...	210	...
Star 1	240	214	200	263	267	288	300	260
	239	210	200	254	265	282	299	262
Star 2	209	222	297	238	266	170	290	138
	208	220	302	231	264	170	290	143
Star 3	290	172	250	208	187	268	220	240
	286	170	251	212	190	265	210	240
Star 4	284	351	378	379	310	322	320	297
	280	353	372	364	319	325	330	290
Star 5	247	342	208	368	267	295	298	378
	242	346	212	362	274	292	302	373
Star 6	241	441	310	470	289	460	320	522
	240	436	310	470	290	452	322	524
Star 7	266	602	335	530	290	580	313	549
	269	600	340	530	290	580	311	548
Star 8	320	426	305	400	372	424	293	389
	320	426	302	396	370	423	295	391
Star 9	384	330	352	354	402	409	330	367
	379	336	352	356	399	407	322	369
Star 10	322	330	290	367	350	404	280	373
	330	327	286	363	349	403	278	371

From the residuals of the comet readings from the mean of each group the probable error of a setting on the comet is found to be about 15 ten-thousandths of a réseau interval. The focal length being nearly 150 réseau intervals, this corresponds to an error of about 2″.

On the other hand the probable error of a star setting, obtained by taking $\frac{1}{\sqrt{2}}$ (mean difference of two settings) is found to be about 2 in the last place, *i.e.* about 0″·3.

The differences between measures of the coordinate y on the same plate, taken in the direct and reversed positions, are shown in Table II.

TABLE II.

(*Coordinate y, Pl.* 14.)

	Exposure (*a*). Dir.	Exposure (*a*). Rev.	Exposure (*b*). Dir.	Exposure (*b*). Rev.	Exposure (*c*). Dir.	Exposure (*c*). Rev.	Exposure (*d*). Dir.	Exposure (*d*). Rev.
Comet	20·6552	20·6588	20·3847	20·3833	20·1903	20·1921	20·0431	20·0393
Star 1	23·6572	23·6563	23·4236	23·4235	23·2671	23·2663	23·1511	23·1512
Star 2	20·4742	20·4739	20·2415	20·2414	20·0852	20·0849	19·9685	19·9679
Star 3	24·2365	24·2363	24·0035	24·0041	23·8476	23·8471	23·7312	23·7310
Star 4	19·8425	19·8425	19·6107	19·6101	19·4574	19·4552	19·3382	19·3370
Star 5	20·4538	20·4531	20·2211	20·2216	20·0652	20·0642	19·9486	19·9484
Star 6	22·3039	22·3042	22·0705	22·0705	21·9148	21·9142	21·7980	21·7971
Star 7	18·8496	18·8501	18·6172	18·6168	18·4624	18·4619	18·3458	18·3450
Star 8	17·4391	17·4394	17·2063	17·2057	17·0496	17·0492	16·9334	16·9337
Star 9	20·8389	20·8397	20·6064	20·6053	20·4515	20·4511	20·3341	20·3331
Star 10	16·9279	16·9278	16·6950	16·6946	16·5385	16·5385	16·4227	16·4220

On looking at Table II. we see that for the stars there appears to be a systematic error due to orientation of the plate. Out of forty differences (direct–reversed) only seven are negative. Moreover, the mean value of the numerical difference = 5·4 in the last place = 0″·7 about. The value of the same quantity, calculated from the probable error of a setting, is only about 0″·4.

But it does not necessarily follow that all the systematic error will be eliminated by taking means. In other plates the difference (direct–reversed) shows a large predominance of negative values, showing that the systematic error, if such there be, is not constant, but varies slowly with the time. The error will only be eliminated in so far as it remains constant in the interval (frequently 24 hours or more) between the direct and the reversed measures.

The agreement, however, is sufficient to show us that the probable error of a measurement of an actual star image in this case is well under half a second of arc.

For the comet the mean numerical difference (direct–reversed) = 26 in the last place. If the difference were an accidental one of the same kind as that between settings in the same orientation, the value should be 21. There being only four such differences to form the mean in this case, the discrepancy seems hardly significant. Moreover, for the comet the difference (direct–reversed) is as much positive as negative, suggesting that the large amount of this difference for the comet is chiefly made up of accidental errors. The suggestion is confirmed by the examination of the differences for comet images on other plates.

5. The stars on the plate having been identified by means of a tracing from the Bonn Durchmusterung Charts, a certain

number, varying from 6 to 10, were selected, such that the mean of the group roughly coincided with the position of the comet.

These stars were taken as comparison stars, and their coordinates, as well as those of the comet, were measured for each exposure.

The centre of the plate was obtained by a rough measurement, and a value assumed for its R.A. and Decl. for each plate. The same position of the assumed centre was used for the various exposures on the same plate, this being found amply sufficient.

The comparison stars were then identified in the Helsingfors, Harvard, and Bonn Zone Catalogues, and their R.A.'s and declinations, brought up for precession to the epoch 1899·0, were found.

Their coordinates ξ, η upon an ideally correct plate having the assumed centering and an assumed scale value l, which was taken to be 150 from a first approximate determination, were calculated.

It then became necessary in all the cases where the plate had originally a réseau, to apply a large orientation correction to the measured coordinates, because the camera had to be attached to the equatorial in such a way that the edges of the plate, to which the lines of the réseau are approximately parallel, made an angle of nearly 45° with the plane through the polar axis.

This orientation correction was determined well within a degree by plotting the measured coordinates $x'y'$ of the stars on tracing paper, and also plotting the calculated coordinates (ξ, η) on another piece of tracing paper. By superposing the two sets of images the angle between the axes of ξ and x' could be read off with ease.

If this angle is θ, and if (x, y) denote the coordinates of any star approximately corrected for orientation, we have

$$x = x' \cos\theta - y' \sin\theta$$
$$y = y' \cos\theta + x' \sin\theta$$

In the case of the two plates 5 and 10, which were measured by fixing on to them another plate provided with a réseau, this difficulty did not occur, for the réseau was carefully placed in approximately the right position.

But the obliquity of the coordinates for the five plates which had originally a réseau was in reality an advantage, because the displacement of the images in passing from one exposure to another having been obtained by turning the slow-motion screw in declination, the various images, instead of lying on a line nearly parallel to a réseau line, were arranged upon a line making an angle of 45° with the réseau lines. This arrangement has recently been suggested by M. Loewy as desirable, and Mr. Hinks has strongly supported this view on the ground that any local defect in a réseau line did not then affect the measures of one coordinate for all the exposures.

6. The coordinates x, y having been obtained for each star and each exposure, the differences

$$\Delta x = \xi - x \qquad \Delta y = \eta - y$$

were written down.

The plate constants were obtained from the solution of the equations of condition by Dyson's approximate method.

It has been shown by Professor Turner (*Monthly Notices*, 1894, vol. liv. p. 489) and by Mr. Hinks ("The Methods of Reduction and Publication of Measures of Celestial Photographs" (*Astronomical Journal*, No. 475)) that this method gives practically as good values of the constants as the least square solution, the labour being much less.

I have accordingly adopted it in the present case. I have also adhered to the use of the six constants for the reduction of a plate. Theoretically, apart from a certain term due to the refraction, we should have

$$a = e,\ b = -d.$$

Sir David Gill urges that the unsymmetrical part of the refraction correction should be first applied and the equations of condition solved for four unknowns. As authorities appear to be divided on this point, it seemed safer, as well as more straightforward, to retain the six constants.

The values of the constants a, b, d, e, calculated separately for each of the 25 exposures measured, are as follows :—

TABLE III.

Plate.	Exposure	Plate Constants.			
		a	*b*	*d*	*e*
5	(*a*)	+·00743	−·00769	+·00870	+·0072
	(*c*)	+·00738	−·00782	+·00885	+·00686
	(*d*)	+·00726	−·00783	+·00862	+·00674
	(*e*)	+·00715	−·00789	+·00866	+·00649
7	(*a*)	+·00592	−·01976	+·01955	+·00536
	(*b*)	+·00549	−·01951	+·01963	+·00545
	(*c*)	+·00522	−·01974	+·01947	+·00547
10	(*a*)	+·00527	+·03401	−·03399	+·00522
	(*b*)	+·00519	+·03228	−·03215	+·00486
	(*c*)	+·00547	+·03219	−·03231	+·00540
	(*d*)	+·00530	+·03229	−·03250	+·00529
11	(*a*)	+·00603	−·00924	+·00924	+·00606
	(*b*)	+·00646	−·00900	+·00902	+·00633
	(*c*)	+·00621	−·00897	+·00900	+·00609
	(*d*)	+·00612	−·00888	+·00928	+·00655

Plate.	Exposure.	Plate Constants.			
		a	*b*	*d*	*e*
14	(*a*)	+·00505	−·04563	+·04574	+·00497
	(*b*)	+·00519	−·04569	+·04553	+·00487
	(*c*)	+·00516	−·04562	+·04572	+·00497
	(*d*)	+·00515	−·04550	+·04546	+·00495
16	(*a*)	+·00576	−·00524	+·00693	+·00573
	(*b*)	+·00712	−·00636	+·00690	+·00536
17	(*a*)	+·00610	−·02339	+·02350	+·00586
	(*b*)	+·00574	−·02312	+·02311	+·00588
	(*c*)	+·00596	−·02305	+·02296	+·00589
	(*d*)	+·00588	−·02313	+·02298	+·00607

The above table shows that the effect of the differential refraction is small as a rule. The relations $a = e$, $b = -d$ are in the majority of cases approximately satisfied, but it should be noted that the plates were taken near the zenith.

One other conclusion comes out from these results, and that is that the plate constants are practically the same for all the exposures on one plate. The assumed centre and the large original orientation correction being in each case the same for all the exposures, we see that the constants a, b, d, e differ very little as we pass from one exposure to another.

There are one or two striking differences, such as b and d of 10 (*a*) as compared with the other exposures of 10 and the divergence between the constants of 16 (*a*) and 16 (*b*). In the case of 10 the probable cause may have been a slight shake which altered the orientation between exposures (*a*) and (*b*).

With regard to 16, no explanation occurs immediately; 16, however, is not a satisfactory plate. The agreement between the actual and calculated Δx's and Δy's for this plate is bad, as will be seen later on; and it appears probable that the conditions were unfavourable on the night when it was taken.

Thus we may take it that, barring shake or accidents of this kind, it is in general perfectly safe to reduce several exposures on the same plate by means of a single set of plate constants a, b, d, e; c and f, of course, varying for each exposure.

7. The values of Δx, Δy for each star were calculated from the plate constants for a number of the exposures. These calculated values were compared with the actual. The results are exhibited in tables IV. and V.

O—C denotes the excess of the observed coordinate of a star over its coordinate calculated from the plate constants.

TABLE IV.

x-coordinate.

O−C.

Exposure.	Star 1	Star 2	Star 3	Star 4	Star 5	Star 6	Star 7	Star 8	Star 9	Star 10	Probable error deduced
5*a*	− 5	− 4	+ 1	−36	+23	+ 7	− 5	− 4	+22	...	11·9
5*e*	0	−10	+ 9	−34	+15	+ 7	− 4	0	+24	...	11·4
7*c*	+ 5	+ 6	− 4	+ 4	− 9	− 6	− 4	+ 7	...	...	5·6
10*a*	+ 6	+ 6	− 8	− 2	− 2	− 4	+ 4	...	...	...	4·6
10*b*	+10	−11	+ 5	+ 3	− 4	0	− 3	...	...	...	5·1
10*c*	+10	0	−16	+ 4	+ 6	− 8	+ 5	...	...	...	7·0
10*d*	0	− 6	+ 4	+ 1	+ 2	+ 5	− 5	...	...	...	3·3
11*a*	+11	−16	−19	+16	− 2	− 9	+12	− 6	+12	...	11·4
11*d*	−24	+ 3	−10	+ 6	− 6	+ 1	+24	0	+ 6	...	8·9
14*b*	0	+ 7	+ 3	+ 6	−23	+ 7	+ 3	−17	+ 9	+ 6	8·1
14*d*	−12	0	− 4	+14	−16	+ 9	+ 4	−18	+12	+11	10·0
16*a*	−30	−21	− 5	−14	+ 6	− 6	+ 1	+43	+27	...	17·0
16*b*	+11	− 5	− 8	+ 2	−20	− 7	−28	+50	+ 6	...	15·2
17*a*	+ 6	+ 3	− 8	+15	− 8	− 7	...	...	...	...	7·8

TABLE V.

y-coordinate.

O−C.

Exposure.	Star 1	Star 2	Star 3	Star 4	Star 5	Star 6	Star 7	Star 8	Star 9	Star 10	Probable error deduced
5*a*	+13	− 9	−19	− 7	− 7	+16	+ 1	−10	+20	...	11·3
5*e*	+11	− 6	− 5	− 6	0	+18	+ 2	−24	+11	...	9·2
7*c*	− 8	0	+ 2	+ 5	+ 3	− 7	+ 2	+ 2	...	...	3·6
10*a*	− 3	− 2	− 6	+13	+10	+12	−23	...	...	...	9·9
10*b*	+16	−19	−22	+20	+26	+ 3	−24	...	...	...	18·6
10*c*	+ 8	−12	−14	+14	+20	+ 4	−19	...	...	...	13·0
10*d*	− 1	− 4	− 4	+14	+10	+ 5	−21	...	...	...	8·4
11*a*	+16	+ 8	−35	−10	−12	+16	+14	+ 5	− 4	...	13·3
11*d*	+ 9	+31	−35	−17	− 6	+26	+13	− 2	−19	...	17·6
14*b*	−12	− 8	+20	+ 1	+ 4	− 5	+10	+ 8	+13	−33	11·4
14*d*	−16	− 1	+25	− 8	+ 1	− 2	− 6	+15	+21	−25	12·0
16*a*	+42	+ 6	−48	−26	−23	0	+23	0	+26	...	21·6
16*b*	+42	+10	−27	−24	−32	− 5	+14	− 6	+30	...	21·1
17*a*	+ 4	+ 2	− 6	+10	− 6	− 3	...	...	...	...	5·2

I have tested the several exposures on one plate when the agreement seemed imperfect in order to see whether the discrepancies were due to local errors in the plate. A glance at the above tables, however, shows that this is not the case. Plates as a whole appear to show a high or small probable error. On investigation of the residuals it will generally be found that the large residuals, which raise the probable error, have the same sign and affect the same stars for all the exposures on one plate.

It appears, therefore, that the divergence resides in the star itself; it may be due to either of two causes: (i.) possible proper motion of the star, which the corrections deduced from the plate constants cannot, of course, allow for: (ii.) errors in the meridian places used. I suspected that the latter might probably not be relied upon much beyond a second of arc, and, in the computed places, only the nearest tenth of a second of R.A., and the nearest second of arc in declination were retained.

Accordingly the quantities ξ and η might themselves be out by something of the order of a second of arc, which is about ·00073 of a réseau interval, or about 7 in the last place. The event, as is shown further, has proved that this was a low estimate.

Excepting in the case of plate 16, which, as stated previously, is unsatisfactory, and of one exposure of 10, *all* the mean divergences amount to less than 2″, and in the case of plates like 7 and 17, for which the conditions appear to have been favourable, the mean divergences are under 1″. For the seven plates these mean divergences are as follows:—

$$\text{Probable divergence in } x = 9{\cdot}36 = 1''{\cdot}28$$
$$\text{,,} \qquad \text{,,} \qquad y = 10{\cdot}87 = 1''{\cdot}49$$

where, not to weight unduly those plates for which the residuals have been calculated for several exposures, the mean of the probable errors for the exposures referring to one plate has been taken as the probable residual for that plate.

If we exclude plate 16 the probable divergences are—

$$\text{Probable divergence in } x = 8{\cdot}23 = 1''{\cdot}13$$
$$\text{,,} \qquad \text{,,} \qquad y = 9{\cdot}78 = 1''{\cdot}34$$

It is interesting to notice that the probable divergence in declination is somewhat greater than the probable divergence in R A.

8. The above, however, do not give the actual probable errors of the star places measured—not only, as has been pointed out, because the meridian places probably are in error, but also because the plate-constants themselves have a probable error, and this will affect the agreement.

I have not been able to obtain the probable errors of the plate constants and of the meridian places directly, but their effect may be allowed for theoretically as follows :—

Consider any residual Δx.

Let ϵ_t be the error in ξ due to wrong meridian place, so that

$$\xi + \epsilon_t = \text{correct computed coordinate.}$$

Let ϵ_x be the error of measurement on the plate, so that

$$x + \epsilon_x = \text{true place of the star on the plate.}$$

Hence accurate difference

$$= \Delta x + \epsilon_t - \epsilon_x.$$

This should be *exactly* fitted by a formula of the type

$$(a + \delta a)x + (b + \delta b)y + c + \delta c,$$

δa, δb, δc being errors of plate constants due to inaccurate meridian places and errors of measurement. Hence

$$\Delta x + \epsilon_t - \epsilon_x = ax + by + c + x\delta a + y\delta b + \delta c.$$

Now let ϵ be the residual O—C, exhibited in the tables

$$\epsilon = \Delta x - ax - by + c$$

$$\therefore \epsilon + \epsilon_t - \epsilon_x = x\delta a + y\delta b + \delta c$$

$$\therefore \epsilon_t - \epsilon_x = (x\delta a + y\delta b + \delta c - \epsilon).$$

Square and sum for the n stars measured

$$\begin{aligned}\Sigma(\epsilon_t - \epsilon_x)^2 = {} & (\delta a)^2\Sigma x^2 + (\delta b)^2\Sigma y^2 + n(\delta c)^2 + \Sigma\epsilon^2 \\ & + 2\delta a\delta b\Sigma xy + 2\delta a\delta c\Sigma x + 2\delta b\delta c\Sigma y \\ & - 2\delta a\Sigma x\epsilon - 2\delta b\Sigma y\epsilon - 2\delta c\Sigma\epsilon\end{aligned}$$

Now if, as has been the case for the present reductions, the comparison stars have been chosen symmetrically about the origin of coordinates x, y we have

$$\Sigma xy = 0 \qquad \Sigma x = 0 \qquad \Sigma y = 0$$

or, at all events, these quantities are small compared with Σx^2, Σy^2, &c.

Further, if the solution for the constants has been by least squares

$$\Sigma x\epsilon = 0 \qquad \Sigma y\epsilon = 0 \qquad \Sigma\epsilon = 0$$

In the present case the solution has been by Dyson's approximate method; but as this gives results practically identical with those of the least square solution, the above equations will be very approximately satisfied.

We have then

$$\Sigma(\epsilon_t - \epsilon_x)^2 = (\delta a)^2\Sigma x^2 + (\delta b)^2\Sigma y^2 + n(\delta c)^2 + \Sigma\epsilon^2.$$

Now let $\bar{\epsilon}_t$, $\bar{\epsilon}_x$ be the errors of mean square of the calculated and the measured places respectively, and let $\bar{\epsilon}$ be the mean-square residual for the n stars on any one plate. Then

$$\bar{\epsilon}_t^2 + \bar{\epsilon}_x^2 = (\delta a)^2 \frac{\Sigma x^2}{n} + (\delta b)^2 \frac{\Sigma y^2}{n} + (\delta c)^2 + \bar{\epsilon}^2$$

provided $\Sigma\epsilon_t\epsilon_x = 0$, which will be the case if the errors in the meridian places and the errors of measurement on the plate are independent.

Sum equations of this kind for a number N of similar sets (*e.g.* exposures) and divide by N. Let $\bar{\epsilon}_a$, $\bar{\epsilon}_b$, $\bar{\epsilon}_c$ be the errors of mean square of a, b, c.

$$\therefore \bar{\epsilon}_a^2 = \frac{\Sigma(\delta a)^2}{N} \quad \bar{\epsilon}_b^2 = \frac{\Sigma(\delta b)^2}{N} \quad \bar{\epsilon}_c^2 = \frac{\Sigma(\delta c)^2}{N}$$

$$\bar{\epsilon}_t^2 + \bar{\epsilon}_x^2 = \bar{\epsilon}_a^2 \frac{\Sigma x^2}{n} + \bar{\epsilon}_b^2 \frac{\Sigma y^2}{n} + \bar{\epsilon}_c^2 + \bar{\epsilon}^2.$$

We have now to find out the values of $\bar{\epsilon}_a$, $\bar{\epsilon}_b$, $\bar{\epsilon}_c$. Consider a set of differences $\Delta x'$, which satisfy equations of condition

$$ax + by + c = \Delta x'.$$

Suppose that, instead of a, b, c, we have determined constants $a+\delta a$, $b+\delta b$, $c+\delta c$.

We now have residuals

$$x\delta a + y\delta b + \delta c.$$

Now if σ = error of mean square of a $\Delta x'$, the probability of any one observation occurring

$$= \text{const.} \times e^{-\frac{(x\delta a + y\delta b + \delta c)^2}{2\sigma^2}}.$$

The probability of the whole n observations is the product

$$\Pi\left(\text{const.} \times e^{-\frac{(x\delta a + y\delta b + \delta c)^2}{2\sigma^2}}\right)$$

$$= \text{const.} \times e^{-\frac{1}{2}\frac{(x\delta a + y\delta b + \delta c)^2}{\sigma^2}}$$

$$= \text{const.} \times e^{-\frac{(\delta a)^2\Sigma x^2}{2\sigma^2} - \frac{(\delta b)^2\Sigma y^2}{2\sigma^2} - (\delta c)^2 \times \frac{n}{2\sigma^2}}$$

the cross-terms going out as before.

This, then, is the probability of the constants $a+\delta a$, $b+\delta b$, $c+\delta c$, coinciding with the given set of observations, *i.e.* the above is the error function for δa, δb, δc.

This gives at once

$$\bar{\epsilon}_a = \frac{\sigma}{\sqrt{\Sigma x^2}} \quad \bar{\epsilon}_b = \frac{\sigma}{\sqrt{\Sigma y^2}} \quad \bar{\epsilon}_c = \frac{\sigma}{\sqrt{n}}.$$

But σ is made up of the errors due both to ξ and to x,

$$\therefore \sigma^2 = \bar{\epsilon}_t^2 + \bar{\epsilon}_x^2.$$

So that finally

$$\bar{\epsilon}_a = \sqrt{\frac{\bar{\epsilon}_t^2 + \bar{\epsilon}_x^2}{\Sigma x^2}} \quad \bar{\epsilon}_b = \sqrt{\frac{\bar{\epsilon}_t^2 + \bar{\epsilon}_x^2}{\Sigma y^2}} \quad \bar{\epsilon}_c = \sqrt{\frac{\bar{\epsilon}_t^2 + \bar{\epsilon}_x^2}{n}}.$$

Substituting now in our original equation, we obtain

$$\bar{\epsilon}_t^2 + \bar{\epsilon}_x^2 = \left(\bar{\epsilon}_t^2 + \bar{\epsilon}_x^2\right)\frac{3}{n} + \bar{\epsilon}^2$$

or

$$\bar{\epsilon}_x^2 = \frac{\bar{\epsilon}^2}{1 - \frac{3}{n}} - \bar{\epsilon}_t^2$$

and multiplying by $(\cdot 6745)^2$ to reduce the error of mean square to probable error

$$p_x^2 = \frac{p^2}{1 - \frac{3}{n}} - p_t^2$$

where p_x, p, p_t are now probable errors.

From this equation we can find the probable error p_t of a meridian place, once the mean residual p and the probable error p_x of a measure are known. A similar equation holds for y and η.

Now we shall almost certainly err on the side of exaggeration if we take for our probable error of a measure that deduced from the (direct–reversed) on p. 565. The p.e. of the difference we have seen is about $0''\cdot 7$. Accordingly the p.e. of a measure is probably less than $\frac{1}{\sqrt{2}} \times 0''\cdot 7 = 0''\cdot 5$.

It must, however, be remembered that p_x includes errors due to (1) bad driving, (2) distortion, (3) tilt of the plate, as well as the error due to actual measurement.

I have no means of estimating the exact amount of these errors in the present case. A rough calculation, however, shows that for the outermost stars, which are 2° from the centre, the error due to a tilt of 2′ or 3′ would only amount to 1 or 2 in the last place. This would hardly be sufficient to affect the probable error to any extent.

The distortion, though a cubic term, may be sensible for the

outermost stars. As to the bad driving, its only effect would be to increase the error of actual measurement (which is known), by making the discs elongated, unless indeed the driving was very irregular, which I do not think was the case.

Altogether I believe $p_x = 0''\cdot5$ is a fair value to take, but in any case I hardly think p_x could exceed $0''\cdot7$.

Taking $p_x = 0''\cdot5$ and $p = 1''\cdot23$, *i.e.* the mean of the values for x and y (Plate 16 omitted), we find

$$p_t = 1''\cdot47.$$

This error includes, besides proper motions and actual errors of meridian observations, errors due to cutting off decimals of a second, not only in the places taken from the Catalogue, but also in the reductions. Mr. Dyson tells me that the probable error of the Zone Catalogues is certainly not greater than $0''\cdot7$. This would leave an error of $1''\cdot4$ due to decimal places neglected. This does not seem an impossible value, seeing errors may have accumulated in the complicated reductions.

9. We are now in a position to obtain the probable error of the deduced position of a measured star on the plate whose meridian place is not known.

In this case the error is due to—

(1) Actual error of measurement.

(2) Error due to bad plate constants.

The errors of the meridian places will indirectly affect the deduced position through (2).

Let x' y' be the measured coordinates of such a star. We require to know the probable error of the quantities

$$x' + ax' + by' + c$$
$$y' + dx' + ey' + f$$

Take the first of these. The error is

$$\delta x' + x'\delta a + a\delta x' + y'\delta b + b\delta y' + \delta c.$$

a, b are always very small, compared with x', y' and the terms $a\delta x'$, $b\delta y'$ are quite insensible. In fact, in computing $ax' + by' + c$, we might well cut off the last two places in x' and y' so that for this purpose the latter may be treated as constant. Hence

$$\text{error} = \delta x' + x'\delta a + y'\delta b + \delta c'.$$

Now suppose we have a group of n' such stars symmetrically situated all round, which are measured with a view to their places being obtained.

Squaring and adding, we find if ϵ' be the error of mean square for the place

$$\epsilon'^2 = \bar{\epsilon}_x^2 + (\delta a)^2 \frac{\Sigma x'^2}{n'} + (\delta b)^2 \frac{\Sigma y'^2}{n'} + (\delta c)^2$$

provided the error of measurement $\delta x'$ is independent of the position of the star on the plate, which, on the face of it, appears likely.

Now if $\frac{\Sigma x'^2}{n'} = k'^2 = \frac{\Sigma y'^2}{n'}$, k' represents the "scatter" of the measured stars about the centre of the plate.

From a number of similar sets we have

$$\epsilon'^2 = \bar{\epsilon}_x^2 + \bar{\epsilon}_a^2 \frac{\Sigma x'^2}{n'} + \bar{\epsilon}_b^2 \frac{\Sigma y'^2}{n'} + \bar{\epsilon}_c^2$$

Now remember that

$$\bar{\epsilon}_a = \frac{\sigma}{\sqrt{\Sigma x^2}} = \frac{\sigma}{\sqrt{n}} \sqrt{\frac{n}{\Sigma x^2}} = \frac{\sigma}{\sqrt{n}} \frac{1}{k}$$

and similarly

$$\bar{\epsilon}_b \quad \dots \quad \dots \quad = \frac{\sigma}{\sqrt{n}} \frac{1}{k}$$

$$\bar{\epsilon}_c \quad \dots \quad \dots \quad = \frac{\sigma}{\sqrt{n}}$$

where k measures the "scatter" of the comparison stars about the centre of the plate. Accordingly

$$\epsilon'^2 = \bar{\epsilon}_x^2 + \frac{\sigma^2}{n}\left(1 + \frac{2k'^2}{k^2}\right)$$

$$= \bar{\epsilon}_x^2 + \frac{1}{n}\left(\bar{\epsilon}_x^2 + \bar{\epsilon}_l^2\right)\left(1 + \frac{2k'^2}{k^2}\right)$$

or in probable errors

$$p'^2 = p_x^2 + \frac{1}{n}(p_x^2 + p_l^2)\left(2\frac{k'^2}{k^2} + 1\right)$$

gives the probable error of a deduced star place.

Two important facts follow at once from the above formula.

(1) The great value of increasing the number n of the comparison stars.

(2) The still greater value of restricting the area over which lie the stars whose places are required to be well inside of the area occupied by the comparison stars, so that k'/k is well under unity.

In our case, taking as before $n = 8$, and supposing the measured stars and the comparison stars to be distributed over the same area, we find, since $k' = k$,

$$p_x = 0''.5 \qquad p_l = 1''.47$$

$$p' = 1''.08$$

or the probable error is about $1''$.

If, as should always be done in practice, the measured star is

picked out of a circle of radius about half that of the circle over which the comparison stars are distributed, $k' = \frac{1}{2}k$, and we find

$$p' = 0''\cdot 83$$

or the probable error of a deduced star place is well under a second of arc.

If we take the higher value for p_x, namely $0''\cdot 7$, the calculated error p' (for $k' = \frac{1}{2}k$) $= 0''\cdot 97$, so that the same conclusion holds.

10. The corrections Δx, Δy for the observed positions of the comet for each exposure were then calculated. This gave ξ and η for the comet. The R.A.'s and declinations obtained by solving back the equations are given in the following table :—

TABLE VI.

Places of Comet 1899 *a* (*Swift*).

Exposure.	Date. 1899.	Camb. S.T. of Middle of Exposure. h m s	R.A. h m s	Decl. ° ′ ″
5*a*	May 19	15 49 35	22 23 44·5	45 18 49
5*c*	,,	15 54 48	22 23 42·6	45 19 16
5*d*	,,	15 59 5	22 23 40·6	45 19 32
5*e*	,,	16 2 16½	22 23 39·2	45 19 46
7*a*	,, 23	17 36 50	21 26 20·6	51 56 19
7*b*	,,	17 43 50	21 26 16·0	51 56 27
7*c*	,,	17 50 36	21 26 11·0	51 56 51
10*a*	,, 26	16 37 55	20 27 12·3	55 41 33
10*b*	,,	17 7 2	20 26 43·8	55 42 46
10*c*	,,	17 16 0	20 26 35·8	55 43 9
10*d*	,,	17 23 0	20 26 29 8	55 43 21
11*a*	,, 29	18 4 10	19 12 44·5	57 21 12
11*b*	,,	18 8 45	19 12 38·7	57 21 18
11*c*	,,	18 13 52	19 12 33·9	57 21 8
11*d*	,,	18 22 7	19 12 25·0	57 21 16
14*a*	,, 31	16 12 8	18 24 34·2	56 53 14
14*b*	,,	16 21 32	18 24 25·7	56 53 4
14*c*	,,	16 27 45	18 24 19·1	56 52 46
14*d*	,,	16 34 55	18 24 12·0	56 52 39
16*a*	June 3	18 29 30	17 15 58·5	53 56 53
16*b*	,,	18 37 0	17 15 51·9	53 56 30
17*a*	,, 5	17 40 30	16 41 8·0	51 9 39
17*b*	,,	17 46 30	16 41 3·8	51 9 10
17*c*	,,	17 54 0	16 40 59·4	51 8 48
17*d*	,,	18 5 30	16 40 52·8	51 8 5

The above are the R.A. and declination of the comet, reduced to the epoch 1899·0, and corrected for precession, nutation, and refraction. The aberration correction, however, has to be considered separately. The part of the aberration due to the motion of the Earth has already been implicitly applied, being involved in the plate constants. But in the case of a comet there is another part, due to the motion of the comet.

Accordingly, in order to obtain from the above data the R.A. and Decl. of the comet free from the effects of aberration, the aberration correction for a star must first be applied with its sign *reversed* and the observations then *antedated* in the manner usual for planets and comets.

11. The accuracy of these comet places will not, owing to the difficulty of measuring a diffuse object, which was occasionally so faint that it required an effort to distinguish it, be comparable with the accuracy of determination of star places as given previously.

A rough determination of the probable error can be made by considering that the changes in R.A. and Decl. for the successive exposures on one plate should be proportional to the time elapsed—a condition which is easily seen from the table not to be accurately satisfied.

Taking the difference of the first and last exposures in each case as giving a more correct value of the rate of change, we can calculate the differences between the 1st and 2nd, 2nd and 3rd, 3rd and 4th, these being proportional to the time.

The deviations from these calculated differences will give us a rough measure of the probable error of the difference of two comet places; dividing this by $\sqrt{2}$ we have the probable error of a comet place.

If we take three of the plates which contain four exposures, viz. 11, 14, 17, and treat them in this way, we obtain the following table—

TABLE VII.

		Differences of R.A.			Differences of Decl.			Differences of Time.
		Obs.	Cal.	Diff.	Obs.	Cal.	Diff.	
		s	s	s	″	″	″	m s
Pl. 11	(b−a)	−5·8	−5·0	·8	+ 6	+ 1	5	4 35
	(c−b)	−4·8	−5·5	·7	−10	+ 1	11	5 7
	(d−c)	−8·9	−9·0	·1	+ 8	+ 2	6	8 15
Pl. 14	(b−a)	−8·5	−9·2	·7	−10	−14	4	9 24
	(c−b)	−6·6	−6·0	·6	−18	−10	8	6 13
	(d−c)	−7·1	−7·0	·1	− 7	−11	4	7 10
Pl. 17	(b−a)	−4·2	−3·6	·6	−29	−23	6	6 0
	(c−b)	−4·4	−4·6	·2	−22	−28	6	7 30
	(d−c)	−6·6	−7·0	·4	−43	−43	0	11 30

Hence

Mean diff. in R.A.	$= 0^s\cdot47$
„ „ Decl.	$= 5''\cdot6$
Probable error in R.A.	$= 0^s\cdot33$
„ „ Decl.	$= 4''\cdot0$

To get the probable error in angle in the direction of ξ we have to multiply $0^s\cdot33$ ($= 5''\cdot0$) by sin (mean N.P.D. for plates 11, 14, 17), *i.e.* sin $35° = \cdot57$.

This gives

p.e. in ξ in arc	$= 2''\cdot9$
p.e. in η „	$= 4''\cdot0$

We may take it therefore that the probable error of any one comet place is under $5''$.

12. The results of these reductions show that photographs taken with an ordinary portrait lens are capable, when measured and reduced, of giving star places to about $1''$. In the case of the comet the accuracy is less than this, the probable error being under $5''$. Such an instrument appears therefore to be well adapted for work not requiring a very high degree of precision.

Incidentally it appears that in reducing such plates it is sufficient, in general, to use the same set of plate constants a, b, d, e for all the exposures on a plate.

The value of increasing the number of the comparison stars, and of taking the stars whose place is to be deduced well *inside* the comparison stars, appears from the consideration of the probable errors.

It is also hoped that the comet places may be of value for comparison with the calculated orbit. I can only express my regret that, from the causes mentioned at the beginning of the paper, these data could not be made available earlier.

In conclusion I wish to thank Sir Robert Ball for kindly allowing me to carry out this work at the Cambridge Observatory, and Professor Karl Pearson, of University College, London, for letting me use the Brunsviga calculating machine belonging to his department, which has proved a great help in the reductions.

I also wish to thank very heartily Mr. Hinks, of the Cambridge Observatory, for the exceedingly valuable assistance and advice, both as regards the observations and the reductions, with which he has always been ready to help me.

Note added 1902 *July* 5.

Since writing the above I have been able to deduce directly the error p_z from the final results. The conclusions as to the numerical value of the probable error p' of star places deduced have been somewhat modified.

If we consider the *differences* of O—C for various exposures, I find the probable error of such a difference for two exposures on one plate to be, both for x and for y,

$$p_{s_0-s_0} = 1''\cdot 00.$$

Now, if we suppose the various exposures reduced to the mean of the stars as origin, we have an equation of condition

$$ax + by + c = \delta\xi - \delta x + \Delta_1 x,$$

$\Delta_1 x$ being the *correct* difference if there were no errors.

The equations giving the constants are :

$$\begin{aligned} a\Sigma x^2 &= \Sigma x\delta\xi - \Sigma x\delta x + \Sigma x\Delta_1 x \\ b\Sigma y^2 &= \Sigma y\delta\xi - \Sigma y\delta x + \Sigma y\Delta_1 x \\ cn &= \Sigma\ \delta\xi - \Sigma\ \delta x + \Sigma\ \Delta_1 x. \end{aligned}$$

We may note in passing that this shows that the errors $\delta\xi - \delta x$ cannot be perfectly random, but must be correlated with the coordinates if an error in the plate constants a, b, c is to exist. For a large number of similar sets, however, the distribution of $\delta\xi - \delta x$ is random, although any *individual* set deviates from the random type.

For another exposure the same equations are :

$$\begin{aligned} a'\Sigma x^2 &= \Sigma x\delta\xi - \Sigma x\delta x' + \Sigma x\Delta_1 x \\ b'\Sigma y^2 &= \Sigma y\delta\xi - \Sigma y\delta x' + \Sigma y\Delta_1 x \\ c'n &= \Sigma\ \delta\xi - \Sigma\ \delta x' + \Sigma\Delta_1 x. \end{aligned}$$

Subtract, and we have :

$$\begin{aligned} (a-a')\Sigma x^2 &= -\Sigma x(\delta x - \delta x') \\ (b-b')\Sigma y^2 &= -\Sigma y(\delta x - \delta x') \\ (c-c')\ n &= -\Sigma\ (\delta x - \delta x'). \end{aligned}$$

The δt's being the same for both exposures.

Now any difference

$$\begin{aligned} &\delta\,(O-C) \\ &= \delta x - \delta x' + (a-a')\,x + (b-b')y + (c-c'). \end{aligned}$$

Square and sum for the n comparison stars :

$$\begin{aligned} &\Sigma\,(\delta O - \delta C)^2 \\ &= \Sigma\,(\delta x - \delta x')^2 + 2(a-a')\,\Sigma x(\delta x - \delta x') \\ &\qquad + 2(b-b')\,\Sigma y(\delta x - \delta x') \\ &\qquad + 2(c-c')\,\Sigma\,(\delta x - \delta x') \\ &\qquad + (a-a')^2\Sigma x^2 \\ &\qquad + (b-b')^2\Sigma y^2 \\ &\qquad + (c-c')^2 n \end{aligned}$$

$$= \Sigma(\delta x - \delta x')^2 - \frac{1}{\Sigma x^2}[\Sigma x(\delta x - \delta x')]^2 - \frac{1}{\Sigma y^2}[\Sigma y(\delta x - \delta x')]^2 - \frac{1}{n}[\Sigma(\delta x - \delta x')]^2 .$$

Sum this again for a large number N of similar sets, then it is easy to show that $p_{x-x'}$, $p_{\delta x - \delta x}$ being probable errors

$$p^2_{x-x'}\left(1 - \frac{3}{n}\right) = p^2_{\delta x - \delta x}$$

whence

$$p_x^2 = \tfrac{1}{2} p^2_{x-x'} = \tfrac{1}{2} 1{\cdot}00 \times \tfrac{8}{5} = ''{\cdot}8$$

$$\therefore p_x = ''{\cdot}9 \text{ nearly.}$$

This shows that my previous estimate was too low, and errors due to bad driving, &c., must have been more important than I thought.

This gives $p_t = 1''{\cdot}26$.

Finally the error of a deduced star place ($k' = \frac{1}{2}k$) $p' = 1''{\cdot}12$.

This is somewhat larger than the previous result. The error of the star place is accordingly slightly above, instead of slightly under, a second of arc.

The magnitude of p_p as stated in the paper, is chiefly to be attributed to the accumulated error in the reductions. This arose through the use of an auxiliary angle, which was computed only to the nearest second.

A Dark Reticle. By Chas. S. Howe, Ph.D., Professor of Astronomy, Case School of Applied Science, Cleveland, Ohio (U.S.A.).

About a year ago it occurred to me that dark reticles might have some advantage over the ordinary reticles for transit circles and almucantars. During the past winter some experiments have been made to test their value. These reticles have been made of thin glass covered with some dark substance, and the lines have been cut through this substance to the surface of the glass. A number of experiments were made to find the best material to form the dark layer; it was finally decided to silver the glass. This has proved very satisfactory: fine, sharp lines can be cut in the silver, and if glass with a perfectly smooth surface has been selected, the star can be seen without any difficulty. The silver covers the centre of the glass only, so that the star can be seen when it comes into the field and until it reaches

the reticle; then it disappears, but as it reaches each wire there is a flash of light and the chronograph key is tapped. For stars near the pole the light does not flash across the line, but lights it up gradually; the star finally comes into view, remains for an instant—hardly more than time enough to tap the key—and then slowly fades away. Some of the theoretical advantages of the new reticle are:—

1st. The probable error of tapping the key upon the flash would be less than upon the bisection of a star with a wire. With an ordinary reticle the eye and the mind of the observer are under a constant strain to determine when a star is bisected, or to estimate when it will be bisected. With the dark reticle the observer looks into a dark eyepiece, sees nothing, and does not try to see anything until the flash comes, when he strikes the key. Except in case of stars much fainter than are ordinarily observed, there is no difficulty in seeing the flash, and there is no strain upon the eye or upon the attention. It would seem, therefore, that the probable error of tapping the chronograph key would be less than in the old method.

2nd. The personal equation would be less for the reasons given above.

3rd. That part of the personal equation depending upon bright field or bright wires would be eliminated, because all stars would be observed with a dark field.

4th. Fainter stars could be observed, because no light would be lost from the bright field or bright wires.

After the observations mentioned in this article had been made it was found that a London firm of instrument makers was advertising in its catalogue a "flashing transit eyepiece" which seemed to be similar to the dark reticle described here. I have not, however, been able to find any record of observations made with it.

In order to test the probable error of tapping the key when the dark reticle was used, the method described in Chauvenet's *Practical Astronomy*, vol. ii. p. 194, was followed. The observations were made with the large almucantar of the Case Observatory.

Let I = the observed interval between two wires for a star of declination δ.

Computed i = I reduced to the angular distance between the same wires.

True i = true angular distance between the same wires.

r = probable error of the angular distance between two wires.

ϵ = probable error of tapping the key on one wire.

Then $r = \cdot 6745\sqrt{\frac{[vv]}{m-1}}$, and $\epsilon = \cdot 6745\sqrt{\frac{[vv]}{2(m-1)}}$.

46 *Leonis Minoris* observed 1902 March 13 gave the following results:—

I	Computed i	True i	V.
s	s	s	
1·84	1·34	1·38	−·04
1·81	1·32	1·35	−·03
1·90	1·38	1·34	+·04
1·90	1·38	1·36	+·02
1·77	1·29	1·38	−·09
1·89	1·38	1·36	+·02
1·77	1·29	1·34	−·05
1·94	1·41	1·35	+·06

Thirty-five stars gave $[vv] = 1{\cdot}6427$, $m = 280$, and $\epsilon = {}^{s}{\cdot}037$.

Twenty-two of these stars were time stars for which $\epsilon = {\cdot}037$; the other thirteen were north of declination 70° and $\epsilon = {\cdot}036$.

Thirty-five stars observed with the ordinary reticle gave $\epsilon = {\cdot}037$. Twenty-seven of these were time stars, and gave $\epsilon = {\cdot}036$; the remaining eight were north of 70° declination, and gave $\epsilon = {\cdot}038$.

So far as the probable error of observation is concerned, there is then no difference between the two reticles. This probable error is undoubtedly made up of several components, but as the subject of this investigation was the comparison of the two reticles it is not necessary to separate them. No observations have yet been made to determine difference of personal equation. The greatest advantage of the dark reticle would seem to be in observations of *very* faint stars, for they would be observed in the same way as the other stars, whereas now they are observed with bright wires in a dark field.

Case Observatory, Cleveland, O. (U.S.A.)

Observation of the Total Eclipse of the Moon, 1902 April 22, at Perth Observatory, Western Australia.

(*Communicated by W. Ernest Cooke, M.A., Government Astronomer.*)

The total eclipse of the Moon was observed here by Mr. Johns with a 10-inch refractor on 1902 April 22. The following phases were noted :—

	h	m	s	
Beginning of totality	6	10	47	G.M.T.
End „	7	35	14	„
Last contact with shadow ...	8	47	34	„

It was cloudy for first contact, and there were passing clouds during last, but at the times of the other observations it was

quite clear. Colour copper, very dark in centre, but bright near edges. Limb easily seen through telescope. No occultations.

Perth Observatory, W.A.:
1902 April 29.

Observations of Jupiter made at Mr. E. Crossley's Observatory, Bermerside, Halifax, during the months of July, August, and September, 1901. By Joseph Gledhill.

The following observations of the bands, spots, &c. on the surface of *Jupiter* were made with the 9-inch Cooke refractor (photo-visual). Owing to the considerable south declination of the planet and the unsettled weather it was impossible on any occasion to obtain a really fine view of the details of the markings on the disc. The highest power used was 240, but 150 was found to be most generally useful.

For shortness the dark bands and bright zones are designated as follows:—

a the S. temperate band.	*f* the S. tropical zone.
b the S. equatorial belt.	*g* the equatorial zone.
c the N. equatorial belt.	*h* the N. tropical zone.
d the N. temperate band.	λ is the longitude of the central meridian System II.
e the N.N. temperate band.	

The one salient feature of the disc during the whole of the opposition was the dark broad double band just S. of the equator (S. equatorial belt). There was never any bright space distinctly seen between the components of this fine belt; but, as in past years, the separation was best seen a little to the west of the preceding shoulder.

The red spot was not seen, but a faint grey wisp was once or twice glimpsed resting on the highest point of the *f* shoulder and bending south and westwards: this was probably the eastern end of the red spot or a marking connecting the eastern end with the *f* shoulder.

No warm colour and no distinct detail were seen in the equatorial zone; indeed, there seemed to be a great sameness of tint or brightness over the whole disc; no zone was notably brighter than any other away from the polar regions.

The N. component of *b* (S. equatorial belt) was usually darker than the S. one, and had many dark spots on it which projected a little into the bright central zone.

July 3, 10^h, $\lambda = 290°$. A dark spot on the N. component of *b* central about $11\frac{1}{2}^h$ ($\lambda = 54°$). *a* and *c* faint grey bands. Rough measures: the double dark band *b* 3″·8 in width; the central bright zone *g*, 3″·8 wide; *a* 1″·4; *f* 2″·3; *c* 1″·4; *h* 3″·2.

July 13, $9\frac{1}{2}^h$, $\lambda = 336°$. *a* as dark or darker than *c*; *b*, as usual, the darkest band and the broadest; the N. component of *b* much darker than the S.; *c* faint and narrow; *d* well marked and as dark as *c*; *e* faint and broader than *d*.

July 15, 9^h, $\lambda = 259°$. *a*, *c*, *d* faint; the western half of *a* is darker than the eastern half. At 10^h, $\lambda = 295°$: zone *f* much narrower than zone *h*; *h* is nearly as wide as *g*; zone *h* is the brightest; the N. component of *b* is much broken up and is darker than the S. component.

July 17, 10^h, $\lambda = 236°$. A grey cloud or large spot lies on the S. edge of the great double S. equatorial belt *b*: it projects into the S. tropical zone until it nearly touches the N. edge of the S. temperate band *a*.

July 19, 10^h, $\lambda = 176°$. The N. component of *b* is much broken up; *a* and *c* are faint; *d* is broader than *c*; *e* (the N. temperate band) is narrow; a faint band is seen to the S. of *a*.

Aug. 15, 8^h, $\lambda = 182°$. The dusky cloud or spot on the S. edge of *b* is seen.

Aug. 16, 8^h, $\lambda = 353°$. A bright gap or break in the S. component of *b* is seen: it was central about $7^h\ 53^m$. *a* is broader than *c* or *d*; *d* is the faintest band.

Aug. 18. About $8^h\ 45^m$ a dark piece of (or dark spot on) the N. component of *b* was central; a similar one precedes it. They are not rounded but rectangular forms. Band *a* is nearer to *b* than *b* is to *c*. At 9^h, $\lambda = 329°$; a bright gap or break in the N. component of *b* was seen: it is close behind the dark spot and on the central meridian.

Aug. 19, 10^h, $\lambda = 166°$. A dark spot on the N. component of *b* seen on central meridian about $10^h\ 18^m$. Bands *c* and *d* darker than *a*; *d* is broader than *a* or *c*.

Aug. 20. A dark spot on *b* was central about $7^h\ 42^m$. A few rough measures were made: S. pole to middle of double band *b* 16″·6; N. pole to same 23″·3; the sum gives the polar diameter, 39″·9. [The computed value is 41″·33.] Width of double band *b* 3″·4; N. edge of *b* to S. edge of *c* 3″·1. A dark spot on *b* was central about $7^h\ 35^m$; a gap in *b* central about $8^h\ 43^m$.

August 22, 8^h. Rough measures: middle of band *b* to S. pole 18″·3; S. pole to S. edge of *b* 15″·6; width of *b* 3″·4; S. pole to N. edge of *b* 18″·3; middle of *b* to *c* 6″·1; *c* to *d* 6″·1; *d* to N. pole 11″·5; *a* to S. pole 12″·2; *a* to middle of *b* 5″·4; polar diameter 41″·5; computed polar diameter from Mr. Crommelin's ephemeris 41″·1. A faint cloudy form lay on the S. edge of *b* and extended southwards quite or nearly across zone *f*: it was central about $9^h\ 17^m$. At 8^h band *a* was fainter than *c* or *d*, and *d* as dark and broader than *c*.

August 24, $7\frac{1}{2}^h$. *a* very faint; *c* nearly as dark as *b*, but of course, as always this opposition, very much narrower; *d* much broader than *a* or *c*. N. of *d* comes a bright zone as wide as *d* is broad. A few measures: S. pole to middle of *b* 16″·9;

middle of ***b*** to ***c*** 6″·8 ; width of ***b*** 4″·5 : N. edge of ***b*** to ***c*** 3″·7 ; ***c*** to N. pole 18″·3 ; ***c*** to S. pole 32″·3 ; central zone ***g*** 4″·5 ; polar diameter 42″·6 [the ephemeris value 40″·9] ; ***a*** very faint from $7\frac{1}{2}^h$ to 9^h. A dark spot on ***b*** (the N. component) was central about 8^h 40^m. About 9^h a few measures were made ; middle of ***b*** to S. pole 18″·4 ; middle of ***b*** to N. pole 23″·6 ; width of ***b*** 4″·6 ; S. edge of ***d*** to N. pole 10″·5 ; N. edge of ***d*** to N. pole 8″·1 ; width of ***d*** 2″·4 ; S. pole to ***a*** 10″·5 ; middle of ***b*** to ***c*** 6″·1 ; ***c*** to ***d*** 4″·7 ; S. edge of ***d*** to N. pole 11″·5 ; width of ***b*** 4″·5 ; S. edge of ***b*** to S. pole 15″·6 ; N. edge of ***b*** to S. pole 20″·3 ; width of ***b*** 4″·7. A dark spot on the N. component of ***b*** was central about 9^h 18^m ; another follows it closely. The bright zone ***h*** is a little wider than bright zone ***g***.

August 27, 7^h, $\lambda = 169°$. ***a*** is faint ; ***d*** is broader than ***c*** ; there is a bright narrow zone N. of band ***d***. A dark spot on the N. component of ***b*** is now near the central meridian. A narrow bright zone lies immediately S. of ***a***. The region N. of ***c*** up to the pole is brighter than the region about the S. pole. The grey spot on ***b*** above named was central about 8^h 22^m : it is faint and diffuse ; its length is about 4″, and the height perhaps about the same.

September 4, 8^h, $\lambda = 327°$. ***a*** is as well seen as ***c*** and ***d***.

September 5, 7^h, $\lambda = 81°$. The ***f*** shoulder is a little W. of the central meridian. ***a*** is faint ; ***c*** is narrow but darker than ***a*** ; ***d*** is broader and darker than ***c***.

September 10, 7^h, $\lambda = 112°$. ***a*** faint ; ***d*** broader than ***c***. 7^h 10^m to 7^h 15^m one (or two ?) dark spots on band ***b*** (N. component) very near or on the meridian ; and the ***f*** shoulder is near the ***p*** limb.

September 11, 7^h, $\lambda = 262°$. ***a*** is fainter than ***c*** or ***d***.

September 15, 8^h, $\lambda = 179°$. The grey spot on the S. edge of ***b*** is seen ; probably on the meridian about 8^h 15^m ; planet low and motion very great.

September 18, 6^h, $\lambda = 197°$. ***a*** faint ; ***c*** broad and well seen ; ***d*** broad and less dark than ***c***. The grey spot on ***b*** central about 6^h 20^m.

September 20, 8^h, $\lambda = 209°$. The grey spot on ***b*** central about 8^h.

October 17, 5^h, $\lambda = 193°$. The grey spot on ***b*** on the central meridian about 5^h ? Violent motion ; Sun just set ; ***a*** faint ; ***c*** darker ; ***d*** still darker and broader than ***a*** or ***c***.

Collecting the transits of the grey spot on the S. edge of ***b*** and lying in and across zone ***f*** we have :

1901.	d	h	m	°
July	17	10	15	245
Aug.	15	8	38	225
	20	7	42	223
	22	9	17	221
	27	8	22	219
Sept.	15	8	15	188?
	18	6	20	209?
	20	8	0	209?
Oct.	17	5	0	193?

Further Observations of the New Star in Perseus made at the Radcliffe Observatory, Oxford.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

This paper is in continuation of the notes on the same subject published in the *Monthly Notices* for March, April, May, June, and November 1901.

No periodical fluctuation of brightness has been noticed, but a gradual diminution at the rate of about 0·01 mag. per diem, as remarked in the last paper (*Monthly Notices*, lxii. No. 1), has been maintained. Accordingly no attempt has been made to keep a continuous watch upon the star, and the observations have been made at comparatively long intervals.

The Nova continues to become more bluish. In the last paper it was pointed out that the star appeared for the most part colourless. From the observers' notes on colour in the present paper it will be seen that a bluish tint has for the most part prevailed.

The faintness of the object, its low altitude, and the increased twilight will probably prevent further observations until the autumn.

The following instruments were employed as indicated in the third column of Table II.

Barclay	10-inch equatorial,	power 90.
	2·7-inch finder	„ 13.
Heliometer	1·8 inch finder	„ 19.

TABLE I.

List of Stars used for Comparison with Nova Persei.

Ref. No.	Name of Star.	Adopted Tabular Magnitude.	Authority for Magnitude.
54	Arg. Z. +44°, 734	6·23	Radcliffe estimations on Harvard Scale.
58	+43, 730	6·57	„ „ „ „ „
61	+41, 631	6·00	Harvard Photom. D.M.
62	+41, 638	6·16	„ „ „
63	+42, 736	7·00	Adopted provisionally.
64	+43, 720	7·25	„ „
65	+43, 732	7·25	Harvard Photom. D.M.
67	+44, 714	7·37	„ „ „
70	+44, 732	7·32	„ „ „
71	+42, 772	7·52	„ „ „
72	+43, 766	8·0	Argelander D.M.
73	+44, 717	8·5	„ „

Ref. No.	Name of Star.	Adopted Tabular Magnitude.	Authority for Magnitude.
74	Arg. Z. +44°, 742	7·76	Harvard Photom. D.M.
75	+43, 728	8·4	Argelander D.M.
76	+43, 729	8·7	„ „
77	+43, 739	9·0	„ „
78	+42, 776	7·8	„ „
79	+42, 767	9·5	„ „
80	+42, 768	8·9	„ „
81	+43, 744	8·6	„ „
82	+43, 746	9·1	„ „
83	+43, 751	9·0	„ „
84	+43, 749	9·0	„ „

TABLE II.

Means of Estimations of Magnitude of Nova Persei.

G.M.T.	Observer.	Aperture of Telescope.	Reference Stars.	Mean Mag.	Adopted Mag. for the Night.
1901. h m		Inch.			
Nov. 15 7 30	R.	1·8	64, 65	7·17	7·17
21 8 30	C.	2·7	65, 64, 70, 67	7·37	
9 20	W.	2·7	65, 64, 54	7·21	7·24
9 20	W.	10·0	65, 64, 58, 62–63	7 07	
28 5 45	W.	2·7	65, 64	7·25	
5 45	W.	10·0	65, 64, 58, 63, 62, 61	6·90	
5 45	R.	2·7	64, 65	7·20	7·20
7 0	C.	2·7	64, 67, 65, 70	7·37	
7 0	C.	10·0	65, 70	7·28	
Dec. 2 8 35	R.	2·7	65, 64	7·30	
8 55	R.	10·0	65, 64	7 40	7·35
4 8 30	W.	2·7	65, 64, 58, 70	7·24	
8 35	W.	10·0	65, 64, 54, 70	7·16	
8 45	R.	2·7	65, 64, 58, 70, 67	7·42	7 32
8 50	R.	10·0	65, 64	7·50	
1902. Jan. 4 9 45	C.	10·0	65, 71, 72, 70	7·52	7·52
28 10 8	C.	10·0	71, 72, 73, 74	7·97	7·97

G.M.T.			Observer.	Aperture of Telescope.	Reference Stars.	Mean Mag.	Adopted Mag for the Night.
1902.	h	m		Inch.			
Feb. 10	11	30	R.	2·7	71, 75, 73, 72, 77	8·08	8·27
	11	30	R.	10·0	71, 76, 73, 72, 77	8·46	
Mar. 12	10	30	R.	10·0	77, 72, 73, 71, 78, 76 80, 79, 81, 82, 83	8·66	8·66
29	10	53	C.	10·0	77, 81, 82, 83, 84, 76	8·80	8·80

Observers' Notes on the Estimation of Magnitude.

1901.
Nov. 15. The Nova, by averted vision, appeared much brighter than other stars of the same magnitude. This peculiarity caused a difficulty in estimating magnitudes. It was not easy to get rid of the bias formed by the first view of the Nova before placing it and the comparison stars successively in the centre of the field. Sky foggy.

Nov. 21. With the 10-inch, power 90, Nova is ½ mag. fainter than No. 58. Bright moonlight (C.). The image of Nova in the 10-inch is sharp and in good focus with those of other stars. No nebulosity, but the sky is moonlit (W.).

Dec. 4. In comparing Nova with Nos. 65 and 64 in the 10-inch, using power 90, I found it was necessary for the best definition to focus each star separately when in centre of field. The margin of the image of Nova seemed narrower to-night than on November 28. No. 64 is duller than No. 65, but I thought its image a trifle larger than No. 65. Sky is clear, but there is some ground-fog, and horizon stars are nearly obliterated (W.). Sky is somewhat foggy, but the field around No. 64 seems blacker than that around the Nova (R.).

1902.
Jan. 28. Observations much interrupted by cloud.

Feb. 10. Field of 2·7-inch "Finder" not clear; object-glass fogged with condensation.

Mar. 12. Nova in the 2·7-inch "Finder" is brighter than No. 77, and fainter than No. 72.

Mar. 29. Passing clouds very troublesome.

Observers' Remarks on Colour of Nova and Comparison Stars.

1901.
Nov. 21. Nova bluish-white in the 10-inch (C.). With the 10-inch, No. 64 reddish; No. 58 very red; a suspicion of red fringe to Nova (W.).

Nov. 28. No. 64 is red in the 2·7-inch. With the 10-inch No. 64 is light red; No. 58 is strongly tinged with red; and the spurious disc of the image of Nova is pearly white with fainter soft white margin (W.). Nova is bluish-white in the 10-inch, with powers 90, 180, and 250 (C.).

Dec. 2. Nova white and No. 64 orange-red in the 10-inch.

Dec. 4. In the 10-inch Nova is opaque-white with a bluish tinge (very slight tint); No. 65 is very light yellow tint and No. 64 a decidedly reddish tint (W.).

1902.
Jan. 4. Nova white in 10-inch. Nos. 70 and 72 deep orange.

Jan. 28. Nos. 72 and 74 orange in the 10-inch. Nova white.

Feb. 10. In the 10-inch No. 72 orange-red and Nova dull.

Mar. 12. Nova is dull and bluish in the 10-inch; No. 72 is orange-red.

Mar. 29. Nova is bluish and dull in the 10-inch.

The observers were:—Mr. Wickham, indicated by W.
Mr. Robinson, „ R.
Mr. McClellan, „ C.

Radcliffe Observatory, Oxford:
1902 *June* 10.

Further Observations of the New Star in Perseus (5).

By A. Stanley Williams.

My early observations of this star up to 1901 June 10 have already been communicated to the Society.* The present paper contains the continuation up to the present time. The photometric magnitudes of a number of the fainter stars in the neighbourhood of the Nova have recently been published by Messrs. G. Müller and P. Kempf in the *Astronomische Nachrichten*, No. 3779, and these magnitudes have been adopted for the comparison stars in reducing the observations. The following is a list of the comparison stars used, with the magnitudes according to Müller and Kempf. The first column contains the designation of the star employed in the present observations.

Comparison Stars.

Designation.	Name.	Magnitude.
(32)	32 Persei	5·18
(36)	36 Persei	5·54
(30)	30 Persei	5·65
b	B.D. + 43°·730	6·57
a	„ + 44°·734	6·61
e	„ + 43°·732	7·41
g	„ + 43°·729	8·70
k	„ + 43°·739	9·11

The above magnitudes have been used in reducing all the telescopic observations. But for those made with the opera-glass the magnitudes of *a* and *b* have been assumed to be 6·25 and 6·50. Both these stars are accompanied by bright companions, and the presence of the latter evidently affected the brightness as observed with the opera-glass. The increase of brightness indicated by the above values is less than what should result from combining the light of the component stars of the two groups, but their adoption renders the opera-glass observations comparable with the telescopic.

According to the photometric observations *b* should be

* See *Monthly Notices*, vol. lxi. pp. 337, 396, 480 and 550.

slightly brighter than *a*, but visually the latter was decidedly brighter than the former. This difference is no doubt due to the orange-red colour of *b*,* and was greater with the 2¾-inch refractor than with the 6½-inch reflector. All the observations have been reduced with a step value of 0·07 mag. In the last column of the following table, 6½ = 6½-inch reflector, p. 50; 2¾ = 2¾-inch refractor, p. 35; 1½ = the 1½-inch finder of the reflector, p. 12; and Op. = opera-glass.

Observations of Brightness of the Nova.

Date. 1901.	G.M.T. h m	Observations.	Magnitude.	Inst.
June 14	13 20	(36) 9 N 6 *a*	6·18	2¾
14	14 5	(36) 8 N 7 *a*	6·11	„
14	14 10	(36) 8 N 8 *a*	6·07	„
17	12 40	(36) 12 N 3 *a*	6·39	„
17	13 15	(36) 12 N 3*a*, N 8 *b*	6·26	„
18	13 0	(36) 10 N 5 *a*	6·25	„
18	13 25	(36) 10 N 5 *a*, (30) 10 N	6·28	„
23	12 40	*a* = N 7 *b*	6·34	„
24	12 30	(36) = N 12 *a*, (30) = N, (32) 5 N	5·62	„
24	13 15	(32) 4 N 15 *a*, N 2 (36), N 2 (30)	5·46	„
24	13 52	(32) 2 N 3 (36), N 3 (30)	5·36	„
26	12 40	(36) 8 N 5 *a*	6·18	„
26	13 10	(36) 9 N 5 *a*, (30) 10 N	6·26	„
27	12 20	(36) 9 N 6 *a*, (30) 9 N	6·21	„
27	12 53	(36) 6 N 8 *a*, (30) 8 N	6·07	„
July 28	12 13	(36) 12 N 2 *a*, N 10 *b*	6·24	„
28	12 25	(36) 9 N 5 *a*	6·21	„
28	13 55	(36) 9 N 6 *a*	6·18	„
29	12 50	(36) 10 N 6 *a*, N 10 *b*	6·10	„
29	13 50	(36) 10 N 4 *a*	6·28	„
Aug. 3	11 50	(36) 10 N 5 *a*	6·25	„
3	13 5	(36) 11 N 4 *a*, N 10 *b*	6·17	„
3	14 55	(36) 8 N 7 *a*	6·11	„
4	12 0	(36) 8 N 5 *a*	6·18	„
6	11 15	(36) 11 N 4 *a*, (30) 10 N	6·33	„
6	14 0	(36) 12 N 3 *a*, N 8 *b*	6·26	„
8	11 30	(36) 8 N 7 *a*, (30) 8 N	6·14	„
8	15 0	N = *a*, N = *b*	6·59	6½

* Comparison with the results of other observers seems to show that red stars appear distinctly fainter to my eye than they do to those of most observers.

Date. 1901.	G.M.T. h m	Observations.	Magnitude.	Inst.
Aug. 8	15 0	N 2 *a*, N 10 *b*	6·17	1½
8	15 0	N 2 *a*, N 10 *b*	6·17	2¾
9	10 55	(36) 8 N 7 *a*, (30) 10 N 15 *b*	6·02	,,
10	12 50	(36) 13 N = *a*, N 8 *b*	6·36	,,
10	15 0	*a* = N 5 *b*	6·41	,,
10	15 0	*a* 1 N	6·32	Op.
11	14 20	(36) 10 N 3 *a*, N 10 *b*	6·17	2¾
11	14 20	*a* 1 N	6·32	Op.
12	12 5	N 1 *a*, N 8 *b*	6·27	2¾
15	11 0	*a* = N 3 *b*, N 10 *c*	6·56	,,
15	13 5	*a* 3 N	6·46	Op.
15	13 15	*a* = N 3 *b*	6·48	2¾
16	11 20	*a* 3 N	6·46	Op.
16	11 30	*a* = N 1 *b*, N 10 *c*	6·61	2¾
16	13 47	*a* 3 N 3 *b*	6·37	Op.
18	10 55	*a* = N 5 *b*, N 12 *c*	6·47	2¾
18	13 15	*a* 3 N 2 *b*	6·41	Op.
18	14 8	*a* 2 N 2 *b*, N 10 *c*	6·63	2¾
19	11 15	N 1 *a*, N 5 *b*, N 12 *c*	6·44	,,
19	14 8	N 2 *a*, N 7 *b*, N 12 *c*	6·37	,,
19	14 8	*a* 2 N 2 *b*	6·37	Op.
20	11 0	*a* 3 N 3 *b*	6·37	,,
20	11 20	*a* = N 4 *b*, N 12 *c*	6·49	2¾
20	14 0	*a* = N 4 *b*, N 12 *c*	6·49	,,
21	10 5	*a* 4 N 1 *b*	6·48	Op.
21	11 5	*a* 2 N 2 *b*, N 10 *c*	6·63	2¾
21	14 10	*a* 4 N 1 *b*	6·48	Op.
22	10 45	*a* = N 5 *b*	6·20	,,
22	11 54	*a* = N 3 *b*, N 12 *c*	6 51	2¾
22	13 30	*a* 3 N 2 *b*	6·41	Op.
22	14 45	*a* 3 N 2 *b*	6·41	,,
23	11 10	*a* 2 N 2 *b*, N 10 *c*	6·63	2¾
23	14 10	*a* 2 N 2 *b*	6·37	Op.
24	?	*a* 5 N = *b*	6·55	,,
24	13 35	*a* 3 N = *b*, N 12 *c*	6·65	2¾
26	10 47	*a* 4 N = *b*, N 10 *c*	6·72	,,
26	14 47	*a* 2·5 N 3·5 *b*	6·34	Op.
26	14 47	*a* 3 N = *b*	6·69	6½
27	13 55	*a* 3 N 1 *b*, N 12 *c*	6·63	2¾

Date. 1901.	G.M.T. h m	Observations.	Magnitude.	Inst.
Aug. 30	16 5	*a* 6 N, *b* 3 N 10 *c*	6·84	6½
Sept. 1	10 45	*a* 3 N = *b*, N 12 *c*	6·65	2¾
1	16 13	*a* 5 N, *b* 3 N 6 *c*	6·91	6½
3	8 30	*a* 5 N = *b*	6·55	Op.
3	10 35	*a* 3 N = *b*, N 12 *c*	6·65	2¾
4	8 48	*a* 5 N = *b*	6·55	Op.
4	10 5	*a* 4 N, *b* 1 N 10 *c*	6·75	2¾
5	9 12	*a* 4 N 1 *b*	6·48	Op.
5	10 8	N 2 *a*, N 5 *b*	6·34	2¾
5	12 50	N 3 *a*, N 6 *b*	6·27	,,
5	14 40	*a* 2 N = *b*, N 8 *c*	6·72	6½
7	9 15	*a* 4 N 1 *b*	6·48	Op.
10	10 0	*a* 4 N 2 *b*	6·44	,,
11	15 0	*a* 5 N = *b*	6·55	,,
14	16 0	*a* 4 N 1 *b*	6·48	,,
17	10 30	*a* 3 N 2 *b*	6·41	,,
18	9 2	*a* 5 N 0·5 *b*	6·53	,,
21	11 15	*a* 5 N 1 *b*	6·51	,,
Oct. 3	8 30	*a* 5 N 1 *b*	6·51	,,
6	7 25	*a* 5 N 1 *b*	6·51	,,
7	9 10	*a* 4 N 2 *b*	6·44	,,
14	9 35	*a* 7 N = *b*	6·62	,,
19	9 25	*a* 7 N	6·74	,,
Nov. 1	9 37	*b* 10 N 5 *c*	7·16	6½
3	8 20	*a* 9 N	6·88	Op.
3	10 5	*a* 12 N, *b* 7 N 6 *c*	7·17	6½
15	12 50	*a* 11 N, *b* 4 N	6·90	Op.
Dec. 10	13 55	*a* 13 N, *b* 7 N	7·07	,,
10	15 20	*b* 12 N = *c*	7·41	2¾
18	15 45	*b* 10 N, *c* 1 N	7·37	,,
1902. Jan. 14	13 40	*b* 10 N, *c* 3 N	7·44	,,
31	12 15	*c* 15 N 17 *h*	8·19	,,
Mar. 4	11 5	*c* 16 N 11 *h*, N 8 *g*	8·34	,,
5	11 15	*c* 15 N 15 *h*, N 8 *g* 9 *h*	8·14	,,
6	8 30	*c* 17 N 11 *h*, N 8 *g*	8·36	,,
Apr. 6	8 30	*g* = N 10 *h*	8·55	,,
24	9 5	*g* 2 N 5 *h*	8·80	,,
28	8 50	N 2 *g*, N 8 *h*	8·55	,,

Notes.

1901.
June 26. A little hazy.
July 28. Object-glass slightly dewed in last observation.
Aug. 3. Thin cirrus cloud may have slightly affected the result.
4. A little thin cloud about.
9. Very clear generally, but patches of haze.
Sept. 1. Slight haze. Sky very bright.
Dec. 10. Exceedingly clear. Nova just distinctly visible in the opera-glass.

Excepting where otherwise noted above, it may be assumed that the conditions were favourable.

The observations show that there was a decided temporary increase in the brightness of the Nova on 1901 June 24; but this seems to be the last instance of the kind, the remarkable fluctuations in brightness having almost completely subsided after this date. I feel confident, however, that some of the smaller changes recorded later were real, and not due simply to errors of observation. In particular the increased brightness of the star on September 5 was undoubtedly real. Apart from these slight changes there has been a nearly continuous decline in brightness. The Nova was seen for the last time with the opera glass on December 10, an exceedingly clear night.

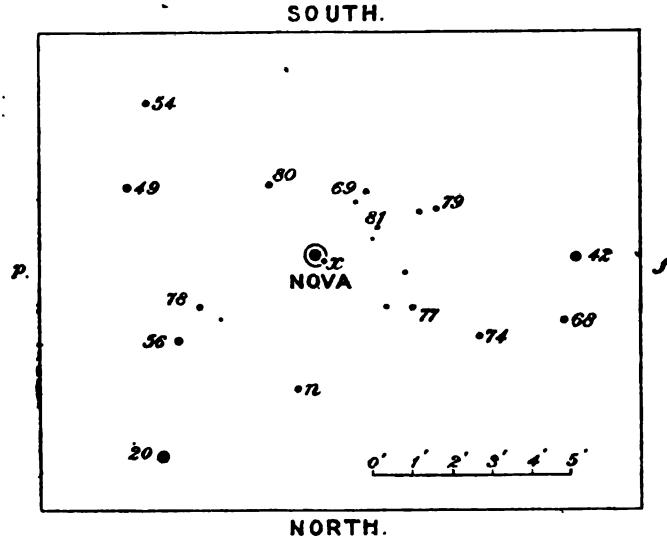
Notes on the Colour of the Star.

1901.
June 14. Little or no red colour, though appearance not the same as that of the comparison stars.
17. Colour seemed strongly reddish, but not more so than *b*.
23. Colour reddish, but not at all marked, and there even seemed at times to be a bluish tinge.
24. Yellowish with pale reddish flashes. On the whole the star was not as red as 36 Persei.
27. Hardly any red colour perceptible.
July 29. Hardly any red colour. The star was indeed slightly bluish, with an occasional yellowish red tinge. It was not nearly so red as *b*.
Aug. 6. Little or no red colour. Certainly not nearly so red as *b*.
8. Quite white, no red colour. No red colour with 6½-inch refl., not even with a Kellner eyepiece which greatly intensifies yellow and red tints.
10. Bluish white, with perhaps occasionally a slight yellowish tinge.
11. Bluish white, with occasional pale reddish flashes.
12. Very pale reddish, not nearly so deep as *b*.
15. White, with occasionally a faint tinge of red or yellow.
18. White (6½-inch. refl. Kellner).
20. White.
22. White, with perhaps a slight reddish or yellowish tinge.
23. White.
26. White (6½-inch refl.). Nova had a perfectly stellar disc, with no trace of nebulosity.
27. White.
30. White (6½-inch refl.). The contrast between the orange red of *b* and the white of the Nova was very striking.
Sept. 1. White.
5. White, with perhaps a slight bluish tinge at times. With the 6½-inch refl. white.
Nov. 1. Bluish white, even with the Kellner (6½-inch refl.).
Dec. 10. Colour seemed slightly greenish.
1902.
Jan. 14. Colour seemed bluish.
31. Distinctly bluish.

All the foregoing observations were made with the 2¾-inch refractor except where otherwise mentioned.

On the Photograph of 1901 *February* 20.

Short particulars of this photograph will be found in the *Monthly Notices*, vol. lxi. p. 337. As it appears that this was the last photograph taken before the apparition of the Nova, it becomes a matter of some interest to determine the magnitude of the faintest star shown by it. Visual estimates of the magnitudes of the fainter stars in this region have been published by Father Hagen * and Professor Aitkin.† The former used a 12-inch refractor, the latter a 36-inch refractor. The positions of most of the stars in the accompanying diagram have been



copied from Aitkin's chart, which is based on micrometer measures. The other stars, with the exception of x, have been added by estimation from Hagen's chart, and the positions of these are consequently not very exact. The numbers of the stars are from Hagen's catalogue. The following is a list of the fainter stars which are visible near the place of the Nova on the photograph of 1901 February 20, with the magnitudes as estimated by Aitkin ‡ and Hagen.

* "Second Chart and Catalogue for observing Nova Persei." See *Popular Astronomy*, vol. ix. p. 279.

† *Publications A.S.P.* vol. xiii. p. 68.

‡ Aitkin remarks that his estimates must be considered as relative rather than absolute.

Star.	Aitkin.	Hagen.	Star.	Aitkin.	Hagen.
49	...	11·0	77	13·0	12·7
54	...	11·4	78	13·2	12·8
56	12·5	11·4	80	13·0	(13)
68	...	12·1	*a*	13·8	...
74	...	12·4			

It seems certain from the foregoing list that if the new star had been as bright as 12·5 mag. on the photometric scale,* it must have left an impression upon this plate, unless it was of a red colour at the time.

In the *Astronomische Nachrichten*, No. 3755, Professor Ceraski has drawn attention to a star of about the 12th magnitude found by M. Blajko upon one of the Moscow photographs† very near to the place of the Nova, which star was completely invisible in a 15-inch refractor in 1901 December. What appears to be the same star is shown, not only by the photograph of 1901 February 20, but also by several other of my photographs of earlier date. The coordinates of the position of the star given by Ceraski are

$$\alpha = \alpha \text{ Nova} + 0^s{\cdot}31 \qquad \delta = \delta \text{ Nova} - 7''.$$

Those from measures of the plate of 1901 February 20 are (for 1855)

$$\alpha = \alpha \text{ Nova} + 0^s{\cdot}88. \qquad \delta = \delta \text{ Nova} + 7''.$$

These positions though not identical are so close that they doubtless refer to the same object. A high degree of accuracy is not to be expected from my measures, as the focal length of the portrait lens with which the photograph was taken is rather short (about 20 inches), and the star discs, even of the faintest stars, are somewhat large, owing to the region of the Nova falling near the edge of the plate. Nevertheless I do not think that the above difference of position can be in error by more than five seconds of arc. The position of x was measured on the plate of 1901 February 20; that of the Nova on a photograph taken on 1902 March 4, by which time the star had faded so much that its image is not very large. The two photographs were taken with the same instrument and under almost exactly similar conditions, and there can be no question as to a possible identification of the Nova with x. The faint star *Hagen* 80 is plainly visible on both plates, and it is evident, even to the eye, that the distance between this star and x is greater than that between it and the Nova.

The question as to what has become of x is a somewhat interesting one. As already stated it was invisible with the

* Hagen's magnitudes agree closely with the photometric determinations of Müller and Kempf down to the 9th magnitude.

† The photograph was obtained 1899 January 30.

15-inch Moscow refractor in 1901 December, whilst Aitkin failed to perceive it with the Lick 36-inch refractor in the spring of the same year.* It is, of course, possible that it is a long period variable, so that its invisibility may be only temporary, but the photographs do not seem to indicate variability. As already mentioned it is shown on several of the photographs taken here; and the following are the estimated photographic magnitudes of x on the different plates, assuming Hagen's visual magnitudes for the stars 49 and 54, and a step value of 0·07 mag.

Date.	Observations.	Magnitude.
1900 Dec. 22	(49) 7 x, (54) 10 x	11·79
1901 Jan. 15	(49) 12 x, (54) 10 x	11·97
25	(49) 12 x, (54) 10 x	11·97
Feb. 20	(49) 10 x, (54) 9 x	11·86

It will be seen that there is here little indication of variability.† The star is also said to be about 12 mag. on the Moscow photograph of 1899 January 30.

Hove: 1902 *May* 20.

Since the above was written Professor Ceraski has very kindly sent me an enlarged print from the Moscow photograph of 1899 January 30. This shows that the brightness of M. Blajko's star is about the same as that of the star x upon my photographs. The position, however, although very close, does not appear to be quite identical, so that it is difficult to conclude with absolute certainty that the same object is represented. This nevertheless is probably the case, the slight difference in position being perhaps due to photographic causes.

Professor E. E. Barnard has recently published micrometer measures of the faint stars in the vicinity of *Nova Persei* made by him with the 40-inch Yerkes refractor (see *Astronomische Nachrichten*, No. 3796). The position of the star x as measured on the photograph of 1901 February 20 corresponds very closely with that of Barnard's star No. 1, the magnitude of which is given by him as 14·7 (position angle 66°·59, dist. 19″·44 from the Nova). This star was overlooked by Aitkin with the 36-inch Lick refractor in the spring of 1901, but the great brightness of the Nova at that time would no doubt account for this.

* The star was looked for here unsuccessfully with the 6½-inch reflector in August or September of 1901, but owing to the brightness of the Nova at that time no importance can be attached to this negative evidence.

† The slightly greater brightness on 1900 December 22 is not real, but due to the fact that the star 49 is abnormally faint on this plate, so as to be slightly fainter than 54, apparently from a photographic defect.

Nova Persei. By Thos. W. Backhouse.

The following table gives details of my observations of Nova *Persei* :—Column 1 gives the date, column 2 the Greenwich mean time of the observation, column 3 the power of instrument used, 4 denoting opera-glasses, 9 the finder, and 20 a $4\frac{1}{4}$-inch refracting telescope. o.f. in this column denotes that the instrument was out of focus. Column 4 gives the assumed relative absorption for the night, calling it 1·0 when it is as clear as it is ever likely to be at the place of observation ; column 5 gives the assumed zenithal absorption in magnitude ; column 6 gives the calculated value of a step, column 7 the resulting magnitudes of the Nova, and 8 the comparison stars.

The last column is reserved for any notes to the observations, as hindrances &c. When the observation is made anywhere else than at Sunderland the place of observation is given in this column.

The method of comparison used is that of Argelander, namely, by step estimations, the Nova being compared with the stars named in column 8. First the magnitudes of the comparison stars in each sequence were computed, using as standards the Harvard photometric magnitudes taken from the Harvard Photometry, with the exception of those for *t*, *v*, *w*, and y^2, which are from the Harvard Durchmusterung. An allowance has been made in the case of *β Geminorum*, *κ Persei*, *t*, and y^2, on account of their ruddy colour, such stars appearing fainter to me than to the Harvard observers. Then an average of these resulting magnitudes for each star was taken, and these averages were adopted as standards for computing the Nova.

t and y^2 have sometimes been observed, but have not been used for obtaining the magnitude of the Nova unless inserted in column 8. Allowance has been made for atmospheric absorption in the cases where it is given in columns 4 and 5 ; in other cases it was not thought it would appreciably affect the result.

The stars with which the Nova has been compared are in *Perseus*, with the exception of *Capella*, *α Canis Minoris*, and *α* and *β Geminorum*, but I have used letters to denote the smaller stars, their identification being as follows :—

u = 36 Persei	*v* = B.D.+44°, 757 }
s = B.D.+45°, 811	„ 759 }
z = B.A.C. 1172	*w* = „ +43°, 730
r = B.D.+45°, 804	*y* = „ +44°, 734
t = „ +44°, 648	y^2 = „ +44°, 732

When the observation of *y* is thought to have included the

neighbouring star y^2, the observed magnitude of the combination has been used.

The adopted magnitudes of the stars are given below with the Harvard photometric value.

	Adopted Mag.	Harvard Mag.		Adopted Mag.	Harvard Mag.
α Can. Min.	0·49	0·46	30 Persei	5·47	5·37
β Gem.	1·29	1·12	*s*	5·57	5·64
α „	1·66	1·56	*s*	5·74	5·71
α Persei	1 98	1·94	*r*	5·96	6·14
β „	2·19	2·31	*y* & y^2	6·04	5·80
ε „	3·04	3·04	*y*	6·27	6·04
ρ „	4·00	4·00	*t*	6·75	6·37
κ „	4·11	3·95	*v*	6·60	6·82
32 „	4·89	4·84	*w*	6·74	6·91
ω „	5·35	5·40	y^2	...	7·32

Sometimes some of the stars were observed in darker sky than others in the same comparison, but no account has been taken of this, as the differences would only be slight.

In two cases where the step value came out very high an assumed value of ·07 magnitude has been used.

In spite of the ruddy colour of the Nova during a considerable part of its apparition it did not appear to be relatively brighter in twilight or moonlight than in a dark sky, as ruddy stars usually do.

Date. 1901.	G.M.T. h m	Power.	Rel. Abs.	Z. Abs.	S. Value.	Mag. of Nova.	Comparison Stars.	Notes.
Feb. 22	11 5	...	...	...	...	Abt. 0·8	...	Sky covered with clouds not uniform.
24	6 23	...	...	...	...	Abt. 0·2	...	S. Shields. Owing to bright twilight, and the sky being covered with more or less cloud, only two stars are visible to the naked eye, Nova Persei and Capella (H.P. mag. 0·2). Owing to irregularities in the clouds it is impossible to tell which is the brighter.
26	10 15	...	1·5	·356	·072	1·27	α Can. Min.; β Gem., α Gem.; α.	Bright moonlight.
26	12 11	...	1·2	·320	·08	1 21	β Gem., α Gem.	„ „

Date. 1901.	G.M.T. h m	Power.	Rel. Abs.	Z. Abs.	S. Value.	Mag. of Nova.	Comparison Stars.	Notes.
Feb. 27	9 35	...	1·5	·356	·065	1·46	β Gem., α Gem.	α Bright moonlight.
Mar. 1	10 20	...	1·4	·344	·085	2·10	α, β.	
2	7 10	...	...	...	·153	2·51	„	Moonlight. Altitudes practically equal.
3	9 50	...	1·0	·296	·068	2·41	α, β, ε.	Bright moonlight.
5	7 17	...	...	...	·07	2·54	„	Altitudes equal.
7	7 55	...	...	...	·079	2·91	β, ε.	„ „
8	9 0	...	...	...	·075	3·12	ε	„ „
9	10 55	...	...	...	·099	3·40	ε, ν.	„ „
12	9 5	...	...	...	·067	3·52	„	„ „
13	8 35	...	...	...	·075	3·80	„	Shields. Altitudes equal.
20	7 40	...	1·0	·296	·094	3·60	„	Twilight.
20	10 20	...	1·0	·263	·078	3·67	„	
21	9 15	...	1·0	·263	·082	3·86	„	
21	11 45	...	...	...	...	4·00	ν	Nova = ν Persei. Altitudes equal.
23	7 51	...	1·0	·296	·067	3·85	ε, ν.	Stockton. Twilight.
23	8 20	...	1·0	·279	·067	3·85	„	Norton, near Stockton. Slight moonlight.
25	10 53	4 o.f.	...	...	·068	5·44	ν, 32, 30	Altitudes equal.
26	10 20	4 o.f.	1·0	·296	·102	4·10	ν, 32.	Bright moonlight.
26	11 50	4 o.f.	1·0	·296	·079	4·00	„	„ „
28	9 15	4 o.f.	1·4	·344	·055	5·00	32, 30	„ „
28	11 35	4 o.f.	1·4	·344	·066	4·80	ν, 32	„ „
28	12 0	4 o.f.	1·2	·320	·063	4·85	„	„ „
28	16 18	4 o.f.	1·0	·296	·04	4·73	„	Twilight.
30	8 40	4 o.f.	1·0	·296	...	3·99	ν	Nova = ν. Brt. moonlight.
31	8 5	4 o.f.	...	...	·064	4·40	ν, 32	Brt. moonlight, alts. equal.
31	8 42	4 o.f.	...	...	·054	4·39	„	„ „
31	9 17	4 o.f.	...	...	·055	4·39	„	„ „
31	9 58	4 o.f.	...	...	·056	4·35	„	„ „
31	10 27	4 o.f.	...	...	·056	4·35	„	„ „
31	11 41	4 o.f.	...	...	·06	4·34	„	Bright moonlight, altitudes practically equal.
Apr. 1	7 56	4 o.f.	1·1	·308	·064	4·19	„	Bright twilight and moonlight.

Date. 1901.	G.M.T. h m	Power.	Rel. Abs.	Z. Abs.	S. Value.	Mag. of Nova.	Comparison Stars.	Notes.
Apr. 1	9 32	4 o.f.	1·1	·308	·073	4·33	ν, 32	Bright moonlight.
1	10 24	4 o.f.	1·1	·308	·066	4·30	„	„ „
1	12 35	4 o.f.	1·1	·308	·06	4·31	„	„ „
4	7 59	4 o.f.	...	...	·079	4·17	„	Bright twilight, altitudes practically equal.
4	8 21	4 o.f.	...	...	·079	4·17	„	Brightish twilight, altitudes practically equal.
4	8 45	4 o.f.	...	...	·087	4·10	„	Brightish moonlight or twilight, alts. equal.
4	9 52	4 o.f.	...	...	·073	4·16	„	Bright moonlight, altitudes equal.
4	10 29	4 o.f.	...	...	·076	4·12	„	„ „
4	11 21	4 o.f.	1·0	·296	·07	4·12	„	Bright moonlight.
5	9 0	4 o.f.	1·0	·279	·073	4·40	„	Slight twilight or moonlight.
5	9 45	4 o.f.	1·0	·296	·066	4·40	„	Moonlight.
8	8 35	4 o.f.	1·0	·296	·075	4·53	„	South Shields. Twilight.
8	9 35	4 o.f.	1·0	·263	·07	4·46	„	
8	10 4	4 o.f.	1·0	·263	·063	4·41	„	
8	15 42	4 o.f.	1·1	·308	·037	4·35	ψ	Bright twilight and moonlight.
9	15 18	9	1·1	·308	·039	4·62	„	Bright moonlight.
9	15 27	4 o.f.	1·1	·308	·041	4·63	„	„ „
11	9 18	4 o.f.	...	...	·041	5·56	30, *s*.	Alts. practically equal.
11	9 39	4 o.f.	...	...	·044	5·55	„	„ „ „
12	9 12	4 o.f.	...	...	·083	4·67	ν, 32.	Altitudes equal.
13	8 54	4 o.f.	...	...	·058	4·42	„	West Hartlepool. Slight twilight, alts. equal.
13	9 25	4 o.f.	...	...	·056	4·40	„	W. Hartlepl. Alts. equal.
14	8 27	4 o.f.	...	...	·073	5·66	30, *s*.	West Hartlepool. Twilight, altitudes equal.
14	8 31	4	...	...	·11	5·60	„	„ „ „
14	8 49	4 o.f.	...	...	·055	5·55	„	West Hartlepool. Slight twilight, alts. equal.
14	9 54	4 o.f.	...	...	·047	5·58	30; *s*	W. Hartlep'l. Alts. equal.
	10 5	4 o.f.	...	...	·044	5·57	„	„ „ „ „
	10 39	4 o.f.	1·1	·280	·023	5·56	„	„ „ Town smoke.

Date. 1901.	G.M.T. h	m	Power.	Rel. Abs.	Z. Abs.	S. Value.	Mag. of Nova.	Comparison Stars.	Notes.
Apr. 14	15	15	4	1·0	·263	·063	5·74	30; ε; y	W. Hartlep'l. Twilight.
	15	33	4	1·0	·263	·195	5·69	30, ε	„ „ Step value assumed ·07 mag. Brightish twilight.
15	8	44	4 o.f.	...	...	·045	5·59	„	Twilight. Alts. equal.
	9	15	4 o.f.	...	...	·066	5·67	„	Slight twilight. Alts. equal
16	10	35	9 o.f.	...	...	·05	5·37	30	Town light. Alts. equal
18	15	28	4	....	...	·100	4·65	κ; 32	Hurworth. Alts. equal.
20	9	5	4	1·3	·313	·06	5·74	30; ε	Twilight.
	9	34	4 o.f.	1·7	·379	·032	5·65	30; ε; y & y^2	
21	9	29	4	2·0	·423	·13	5·67	30, ε	Slight twilight and moonlight. Step value assumed ·07 mag.
24	9	47	4 o.f.	...	...	·066	5·57	„	Moonlight. Alts. equal.
25	10	33	4	1·0	·263	·053	5·79	30; ε; y	„
26	9	22	4	1·0	·263	·048	5·72	30; ε	„
May 4	10	5	20	...	...	·104	5·79	30; y	Bright twilight. Alts. equal.
15	10	9	4	1·2	·324	·049	5·85	„	Torquay. Twilight.
16	10	15	4	1·3	·330	·037	5·83	„	„ Brightish twilight.
20	13	40	4	1·0	·263	·045	5·57	32; 30	London. Brightish twilight.
24	13	25	4	1·0	·263	·073	5·78	32; 30; y	London. Brightish twilight.
June 1	12	20	20 o.f.	1·0	·296	·063	5·77	30; y	Bright twilight.
5	12	10	20 o.f.	1·0	·296	·066	5·92	„	„ „
			20	1·0	·263	·061	6·05	32; u; 30; y; v; w	„ „
8	11	10	20	1·5	·346	·076	4·69	v; κ; 32; 30	„ „
9	12	15	20	1·0	·263	·057	5·95	32; u; 30; y; v	„ „
10	11	3	20	1·0	·263	·054	5·96	30; y	„ „
	12	15	20 o.f.	1·0	·296	·058	5·96	„	„ „
	12	25	20	1·0	·263	·046	5·87	„	„ „
11	11	12	20	1·0	·263	·056	5·03	32; 30	„ „
12	11	20	20	1·0	·263	·073	5·85	30; y	„ „
	11	35	20	1·0	·263	·063	5·90	„	„ „

Date. 1901.	G.M.T. h	m	Power.	Rel. Abs.	Z. Abs.	S. Value.	Mag. of Nova.	Comparison Stars.	Notes.
June 12	12	10	20	1·0	·263	·066	5·93	30; *y*	Bright twilight.
			20 o.f.	1·0	·296	·069	5·87	„	„ „
18	12	15	20	·5	·356	·059	6·04	30; *z*; *y*	„ „
July 2	11	23	20	1·3	·313	·065	5·90	30; *y*	„ „
13	10	45	20	1·2	·296	·053	6·09	*s*; *z*; *r*; *y*	„ „
15	12	15	4	1·0	·263	·058	5·70	30; *z*; *y*	Brightish twilight.
26	13	20	4 o.f.	...	...	·063	5·84	30; *y* & y^2	Alts. equal. Slight twilight.
Aug. 4	11	20	4	...	...	063	6·03	*z*	Alts. equal. Bright moonlight.
19	13	0	4 o.f.	...	...	·066	5·94	*u*; 30; *s*; *z*; *r*; *y* & y^2	Alts. equal.
21	11	50	4 o.f.	...	...	·063	5·89	*z*; *y* & y^2	„ „
22	10	40	4 o.f.	...	...	·063	5·94	„	„ „ Sky light with electric light.
24	10	40	20 o.f.	...	...	·063	6·18	*z*; *y*	Alts. equal. Bright moonlight.
26	11	50	4 o.f.	...	...	...	6·04	*y* & y^2	Moonlight. Alts. equal.
	14	0	20 o.f.	...	...	·056	6·20	*u*; 30; *s*; *z*; *r*; *y*; *v*	Alts. equal.
	14	45	4 o.f.	...	...	·052	6·14	*u*; 30; *s*; *z*; *r*; *y* & y^2; *v*	„ „
27	10	40	4	...	...	·063	6·14	*z*; *y*	„ „ Bright moonlt.
28	10	40	20 o.f.	...	...	·051	6·26	*s*; *z*; *r*; *y*; *v*	„ „ „ „
31	9	50	20 o.f.	...	...	·042	6·27	*z*; *r*; *y*; *v*	„ „ „ „
Sept. 1	12	15	20 o.f.	...	...	·044	6·25	*s*; *z*; *r*; *y*; *v*	„ „ „ „
4	10	15	4 o.f.	...	...	·042	6·06	*s*; *z*; *r*; *y* & y^2	„ „ Slight moonlt.
	10	30	20 o.f.	...	...	·069	6·29	*r*; *y*; *v*	„ „ Moonlight.
	11	10	4	...	...	·06	6·15	„	„ „ „
5	10	50	4 o.f.	...	...	·063	6·08	*s*; *r*; *y* & y^2; *v*	„ „ Slight moonlt.
	11	50	20 o.f.	...	...	·055	6·25	*z*; *r*; *y*; *v*	„ „ „ „
			4 o.f.	...	...	·061	6·21	*y*	Broughty Ferry. Alts. equal.
26	10	40	20 o.f.	...	...	·044	6·42	*z*; *r*; *y*; *v*	Alts. equal. Moonlight.
Oct. 4	10	15	4 o.f.	...	...	·074	6·47	*r*; *y* & y^2; *v*	„
	10	20	20 o.f.	...	...	·063	6·55	*r*; *y*; *v*	„
5	10	3	4 o.f.	...	...	·084	6·36	*y* & y^2; *v*	„

Date. 1901.	G.M.T. h	m	Power.	Rel. Abs.	Z. Abs.	S. Value.	Mag. of Nova.	Comparison Stars.	Notes.	
Oct. 6	10	3	4 o.f.	...	...	·063	6·40	y & y^2; v	Alts. equal.	
7	10	25	4 o.f.	...	...	·068	6·40	„	„	
8	11	55	4 o.f.	...	...	·063	6·40	„	„	
9	9	42	20 o.f.	...	...	·067	6·57	y; v	„	
10	10	25	4 o.f.	...	...	·078	6·42	y & y^2; v	„	
	10	40	20 o.f.	...	...	·078	6·51	y; v	„	
11	10	30	4 o.f.	...	...	·055	6·41	y & y^2; v	„	
17	9	50	4 o.f.	...	...	·063	6·43	„	„	
25	10	50	20 o.f.	...	...	·103	6·74	y; v	„	Moonlight.
Nov. 12	7	55	4 o.f.	...	...	·063	6·66	t; v	„	
15	8	15	4 o.f.	...	...	·063	6·69	„	„	

West Hendon House, Sunderland.

Ephemeris for Physical Observations of

Greenwich Noon. 1902.	P.	L−O.	B.	A−L.	*B.*	Q.	*B.*
	°	°	°	°	°	°	°
Oct. 5	3·03	231·89	+20·90	...	+10·66	289·26	29·24
7	3·82	233·14	21·19	...	11·02	289·56	29·51
9	4·60	234·39	21·47	29·22	11·38	289·85	29·79
11	5·37	235·64	21·74	...	11·73	290·12	30·06
13	6·14	236·89	22·00	...	12·08	290·38	30·33
15	6·90	238·14	22·25	...	12·43	290·63	30·59
17	7·66	239·39	22·49	30·75	12·77	290·87	30·85
19	8·41	240·63	22·71	...	13·11	291·10	31·11
21	9·16	241·88	22·92	...	13·44	291·32	31·36
23	9·90	243·12	23·12	...	13·77	291·53	31·61
25	10·64	244·36	23·31	32·24	14·10	291·73	31·86
27	11·37	245·60	23·48	...	14·42	291·92	32·11
29	12·09	246·83	23·64	...	14·74	292·10	32·34
31	12·80	248·06	23·79	...	15·06	292·28	32·58
Nov. 2	13·51	249·29	23·94	33·67	15·37	292·44	32·81
4	14·21	250·52	24·08	...	15·68	292·59	33·04
6	14·90	251·74	24·20	...	15·99	292·73	33·26
8	15·58	252·95	24·31	...	16·29	292·86	33·48
10	16·25	254·16	24·41	34·99	16·59	292·98	33·68
12	16·92	255·37	24·49	...	16·88	293·09	33·89
14	17·58	256·57	24·56	...	17·17	293·19	34·09
16	18·22	257·75	24·62	...	17·46	293·28	34·28
18	18·86	258·93	24·67	36·26	17·74	293·36	34·47
20	19·49	260·11	24·71	...	18·02	293·43	34·65
22	20·11	261·28	24·75	...	18·29	293·50	34·82
24	20·71	262·44	24·78	...	18·55	293·56	34·98
26	21·30	263·58	24·80	37·35	18·81	293·61	35·13
28	21·88	264·72	24·81	...	19·07	293·65	35·28
30	22·44	265·84	24·80	...	19·32	293·68	35·41
Dec. 2	22·99	266·95	24·78	...	19·57	293·70	35·54
4	23·53	268·05	24·75	38·23	19·81	293·71	35·66
6	24·07	269·15	24·71	...	20·05	293·72	35·77
8	24·59	270·23	24·66	...	20·29	293·72	35·87
10	25·10	271·30	24·61	...	20·52	293·71	35·96
12	25·59	272·35	+24·55	38·91	+20·75	293·69	36·04

Mars, 1902–3. By A. C. D. Crommelin.

Greenwich Noon. 1902.	☉	Light Time.	Appar. Diam.	Defect of Illumination.	Central Meridian.	Passage of Zero Meridian.	
	°	m	″	″	°	h m	h m
Oct. 5	...	16·836	4·60	0·29	106·86	17 20·64	18 0·61
7	...	16·725	4·62	0·30	87·42	18 40·57	19 20·53
9	27·46	16·612	4·66	0·31	67·98	20 0·49	20 40·45
11	...	16·498	4·69	0·32	48·54	21 20·40	22 0·36
13	...	16·383	4·72	0·33	29·10	22 40·31	23 20·25
15	...	16·264	4·76	0·33	9·67	...	0 0·19
17	31·13	16·144	4·79	0·34	350·24	0 40·13	1 20·06
19	...	16·023	4·82	0·35	330·81	2 0·00	2 39·94
21	...	15·900	4·86	0·36	311·38	3 19·87	3 59·81
23	...	15·775	4·90	0·37	291·95	4 39·74	5 19·67
25	34·77	15·648	4·94	0·37	272·52	5 59·60	6 39·52
27	...	15·519	4·98	0·38	253·10	7 19·44	7 59·36
29	...	15·388	5·02	0·39	233·68	8 39·28	9 19·19
31	...	15·256	5·07	0·40	214·26	9 59·10	10 39·00
Nov. 2	38·38	15·123	5·11	0·41	194·85	11 18·90	11 58·79
4	...	14·988	5·16	0·42	175·44	12 38·67	13 18·55
6	...	14·851	5·21	0·43	156·04	13 58·42	14 38·29
8	...	14·712	5·26	0·43	136·64	15 18·15	15 58·01
10	41·97	14·572	5·31	0·44	117·25	16 37·87	17 17·72
12	...	14·430	5·36	0·45	97·86	17 57·56	18 37·40
14	...	14·287	5·41	0·46	78·48	19 17·23	19 57·05
16	...	14·143	5·47	0·47	59·10	20 36·86	21 16·66
18	45·53	13·997	5·53	0·48	39·73	21 56·46	22 36·24
20	...	13·850	5·58	0·49	20·38	23 16·00	23 55·74
22	...	13·701	5·64	0·50	1·04	...	0 35·45
24	...	13·551	5·70	0·51	341·71	1 15·16	1 54·87
26	49·08	13·400	5·77	0·52	322·39	2 34·57	3 14·26
28	...	13·248	5·84	0·53	303·08	3 53·94	4 33·61
30	...	13·094	5·91	0·54	283·78	5 13·27	5 52·92
Dec. 2	...	12·939	5·98	0·55	264·49	6 32·56	7 12·18
4	52·62	12·783	6·05	0·56	245·21	7 51·79	8 31·39
6	...	12·627	6·12	0·57	225·94	9 10·98	9 50·56
8	...	12·469	6·20	0·59	206·68	10 30·12	11 9·66
10	...	12·311	6·28	0·60	187·43	11 49·19	12 28·71
12	56·14	12·152	6·36	0·61	168·20	13 8·23	13 47·70

Greenwich Noon. 1902.	P.	L−O.	B.	A−L.	B.	Q.	R.
	°	°	°	°	°	°	°
Dec. 14	26·07	273·38	+24·49	...	+20·97	293·67	36·10
16	26·53	274·40	24·42	...	21·19	293·64	36·15
18	26·98	275·40	24·34	...	21·40	293·60	36·20
20	27·42	276·38	24·25	39·29	21·60	293·56	36·23
22	27·84	277·35	24·16	...	21·80	293·51	36·24
24	28·24	278·30	24·06	...	21·99	293·45	36·24
26	28·63	279·23	23·96	...	22·18	293·38	36·22
28	29·01	280·14	23·85	39·38	22·36	293·30	36·18
30	29·38	281·03	23·73	...	22·54	293·21	36·13
1903. Jan. 1	29·73	281·90	23·61	...	22·71	293·11	36·06
3	30·07	282·75	23·49	...	22·88	293·02	35·97
5	30·39	283·57	23·37	39·08	23·04	292·92	35·85
7	30·70	284·36	23·25	...	23·20	292·82	35·72
9	31·00	285·13	23·12	...	23·35	292·72	35·57
11	31·28	285·88	22·99	...	23·50	292·61	35·40
13	31·54	286·60	22·86	38·37	23·64	292·50	35·20
15	31·79	287·29	22·73	...	23·77	292·38	34·98
17	32·03	287·95	22·60	...	23·90	292·26	34·73
19	32·25	288·59	22·47	...	24·02	292·14	34·46
21	32·46	289·19	22·34	37·17	24·14	292·01	34·15
23	32·65	289·76	22·22	...	24·25	291·87	33·82
25	32·83	290·29	22·10	...	24·36	291·73	33·45
27	33·00	290·78	21·99	...	24·46	291·60	33·05
29	33·15	291·24	21·88	35·41	24·55	291·47	32·62
31	33·29	291·66	21·77	...	24·64	291·32	32·15
Feb. 2	33·41	292·05	21·66	...	24·72	291·15	31·65
4	33·52	292·39	21·56	...	24·79	290·98	31·11
6	33·61	292·69	21·47	33·03	24·86	290·80	30·53
8	33·69	292·95	21·39	...	24·92	290·61	29·91
10	33·76	293·17	21·32	...	24·98	290·42	29·24
12	33·81	293·35	21·26	...	25·03	290·21	28·54
14	33·85	293·47	21·21	29·94	25·08	290·01	27·79
16	33·87	293·52	21·17	...	25·12	289·80	26·99
18	33·87	293·54	21·14	...	25·15	289·57	26·14
20	33·86	293·51	21·11	...	25·17	289·33	25·24
22	33·85	293 45	21·09	26·02	25·19	289·08	24·29
24	33·81	293·34	+21·10	...	+25·20	288·83	23·30

Greenwich Noon. 1902.		⊙	Light Time.	Appar. Diam.	Defect of Illumination.	Central Meridian.	Passage of Zero Meridian.	
		°	m	″	″	°	h m	h m
Dec.	14	...	11·992	6·45	0·62	148·99	14 27·16	15 6·61
	16	...	11·831	6·54	0·63	129·79	15 46·04	16 25·45
	18	...	11·670	6·63	0·64	110·61	17 4·84	17 44·20
	20	59·64	11·508	6·72	0·65	91·45	18 23·53	19 2·84
	22	...	11·346	6·82	0·66	72·31	19 42·14	20 21·42
	24	...	11·183	6·92	0·67	53·19	21 0·68	21 39·92
	26	...	11·019	7·02	0·68	34·09	22 19·14	22 58·35
	28	63·14	10·856	7·13	0·69	15·00	23 37·54	...
	30	...	10·692	7·24	0·70	355·93	0 16·71	0 55·86
1903. Jan.	1	...	10·528	7·35	0·71	336·88	1 34·99	2 14·08
	3	...	10·363	7·46	0·71	317·86	2 53·13	3 32·16
	5	66·64	10·199	7·58	0·72	298·86	4 11·17	4 50·15
	7	...	10·036	7·70	0·73	279·89	5 29·10	6 8·03
	9	...	9·873	7·83	0·73	260·94	6 46·93	7 25·80
	11	...	9·710	7·96	0·74	242·02	8 4·63	8 43·43
	13	70·13	9·548	8·10	0·75	223·13	9 22·21	10 0·96
	15	...	9·386	8·24	0·75	204·27	10 39·68	11 18·36
	17	...	9·225	8·38	0·75	185·43	11 57·01	12 35·63
	19	...	9·064	8·53	0·75	166·62	13 14·22	13 52·79
	21	73·63	8·904	8·68	0·75	147·84	14 31·33	15 9·83
	23	...	8·745	8·84	0·74	129·09	15 48·29	16 26·70
	25	...	8·588	9·00	0·74	110·38	17 5·07	17 43·40
	27	...	8·432	9·17	0·74	91·70	18 21·70	18 59·96
	29	77·12	8·277	9·34	0·73	73·06	19 38·18	20 16·35
	31	...	8·124	9·52	0·72	54·46	20 54·48	21 32·57
Feb.	2	...	7·974	9·70	0·72	35·90	22 10·62	22 48·63
	4	...	7·826	9·88	0·71	17·38	23 26·61	...
	6	80·62	7·679	10·07	0·69	358·89	0 4·56	0 42·44
	8	...	7·534	10·26	0·68	340·45	1 20·26	1 58·03
	10	...	7·392	10·46	0·66	322·05	2 35·76	3 13·44
	12	...	7·253	10·66	0·64	303·70	3 51·07	4 28·64
	14	84·13	7·116	10·87	0·63	285·40	5 6·16	5 43·63
	16	...	6·983	11·08	0·61	267·14	6 21·06	6 58·44
	18	...	6·853	11·29	0·59	248·93	7 35·77	8 13·04
	20	...	6·726	11·50	0·56	230·77	8 50·25	9 27·40
	22	87·65	6·603	11·71	0·53	212·67	10 4·49	10 41·52
	24	...	6·485	11·93	0·49	194·62	11 18·49	11 55·40

Greenwich Noon. 1903.	P.	L—O.	B.	A—L.	B.	Q.	R.
	°	°	°	°	°	°	°
Feb. 26	33·75	293·16	+21·12	...	+25·21	288·56	22·24
28	33·67	292·90	21·14	...	25·21	288·26	21·14
Mar. 2	33·57	292·60	21·17	21·28	25·21	287·85	19·99
4	33·45	292·24	21·22	...	25·20	287·33	18·78
6	33·32	291·83	21·28	...	25·17	286·7	17·52
8	33·17	291·38	21·35	...	25·14	286·1	16·21
10	33·00	290·87	21·43	15·63	25·11	285·3	14·86
12	32·82	290·30	21·52	...	25·07	284·4	13·46
14	32·62	289·70	21·63	...	25·03	283	12·02
16	32·40	289·07	21·74	...	24·98	281	10·55
18	32·16	288·39	21·86	9·22	24·92	279	9·04
20	31·90	287·67	22·00	...	24·86	277	7·52
22	31·63	286·91	22·14	...	24·79	274	5·99
24	31·35	286·13	22·28	...	24·71	270	4·46
26	31·06	285·34	22·42	2·23	24·62	264	3·05
28	30·76	284·53	22·56	...	24·53	...	2·04
30	30·44	283·70	22·71	...	24·43	...	2·14
Apr. 1	30·10	282·85	22·85	...	24·33	147	3·26
3	29·77	282·03	23·00	5·04	24·22	140	4·73
5	29·45	281·23	23·14	...	24·10	134	6·29
7	29·13	280·45	23·29	...	23·98	129	7·87
9	28·81	279·68	23·43	...	23·85	125	9·46
11	28·50	278·93	23·57	12·08	23·71	121·9	11·03
13	28·20	278·20	23·71	...	23·56	120·6	12·59
15	27·90	277·53	23·84	...	23·41	119·6	14·11
17	27·63	276·93	23·97	...	23·25	118·8	15·60
19	27·37	276·36	24·09	18·59	23·09	118·0	17·06
21	27·13	275·82	24·21	...	22·92	117·36	18·47
23	26·91	275·30	24·33	...	22·75	116·86	19·84
25	26·72	274·85	24·44	...	22·57	116·43	21·16
27	26·55	274·48	24·55	24·41	22·38	116·06	22·43
29	26·41	274·16	24·65	...	22·19	115·73	23·65
May 1	26·29	273·90	24·75	...	21·99	115·43	24·82
3	26·20	273·70	24·85	...	21·78	115·17	25·95
5	26·13	273·55	24·95	29·27	21·56	114·97	27·01
7	26·09	273·46	25·04	...	21·34	114·80	28·03
9	26·08	273·43	25·13	...	21·11	114·65	29·00
11	26·08	273·47	+25·21	...	+20·88	114·51	29·92

Greenwich Noon. 1903.	⊙	Light Time.	Appar. Diam.	Defect of Illumination.	Central Meridian.	Passage of Zero Meridian.	
	°	m	″	″	°	h m	h m
Feb. 26	...	6·372	12·14	0·45	176·63	12 32·25	13 9·05
28	...	6·263	12·35	0·41	158·68	13 45·80	14 22·50
Mar. 2	91·19	6·158	12·56	0·37	140·79	14 59·14	15 35·72
4	...	6·058	12·77	0·33	122·95	16 12·24	16 48·69
6	...	5·964	12·97	0·29	105·17	17 25·08	18 1·42
8	...	5·875	13·16	0·25	87·44	18 37·71	19 13·95
10	94·73	5·791	13·35	0·21	69·76	19 50·15	20 26·31
12	...	5·714	13·53	0·18	52·11	21 2·44	21 38·53
14	...	5·643	13·70	0·15	34·50	22 14·58	22 50·56
16	...	5·578	13·86	0·12	16·94	23 26·47	...
18	98·30	5·520	14·01	0·09	359·44	0 2·30	0 38·12
20	...	5·468	14·14	0·07	341·97	1 13·92	1 49·71
22	...	5·423	14·26	0·04	324·51	2 25·49	3 1·25
24	...	5·385	14·36	0·02	307·06	3 36·99	4 12·71
26	101·89	5·355	14·44	0·01	289·64	4 48·41	5 24·08
28	...	5·332	14·50	0·00	272·25	5 59·72	6 35·33
30	...	5·316	14·54	0·00	254·87	7 10·91	7 46·51
Apr. 1	...	5·307	14·56	0·01	237·49	8 22·12	8 57·76
3	105·51	5·305	14·57	0·02	220·09	9 33·52	10 9·19
5	...	5·311	14·56	0·04	202·67	10 44·89	11 20·61
7	...	5·323	14·53	0·06	185·25	11 56·34	12 32·09
9	...	5·342	14·48	0·09	167·81	13 7·87	13 43·69
11	109·15	5·367	14·41	0·13	150·34	14 19·56	14 55·48
13	...	5·399	14·32	0·16	132·82	15 31·45	16 7·46
15	...	5·437	14·22	0·21	115·25	16 43·52	17 19·62
17	...	5·481	14·10	0·26	97·65	17 55·76	18 31·94
19	112·82	5·531	13·97	0·31	80·01	19 8·16	19 44·44
21	...	5·587	13·83	0·36	62·33	20 20·78	20 57·19
23	...	5·648	13·68	0·41	44·58	21 33·66	22 10·19
25	...	5·713	13·53	0·46	26·78	22 46·78	23 23·42
27	116·52	5·783	13·37	0·51	8·92	...	0 0·12
29	...	5·857	13·20	0·56	351·01	0 36·88	1 13·71
May 1	...	5·936	13·03	0·61	333·04	1 50·61	2 27·58
3	...	6·019	12·85	0·65	315·01	3 4·61	3 41·70
5	120·26	6·105	12·67	0·69	296·92	4 18·84	4 56·06
7	...	6·194	12·49	0·73	278·76	5 33·35	6 10·72
9	...	6·287	12·30	0·77	260·55	6 48·16	7 25·64
11	...	6·382	12·11	0·81	242·28	8 3·17	8 40·74

Greenwich Noon. 1903.	P.	L−O.	B.	A−L.	*B.*	Q.	E.
	°	°	°	°	°	c	°
May 13	26·12	273·55	+25·29	33·19	+20·64	114·39	30·80
15	26·18	273·68	25·36	...	20·39	114·29	31·63
17	26·26	273·87	25·43	...	20·14	114·19	32·41
19	26·37	274·11	25·50	...	19·88	114·10	33·15
21	26·50	274·40	25·56	36·26	19·62	114·01	33·85
23	26·65	274·73	25·62	...	19·35	113·94	34·51
25	26·82	275·11	25·68	...	19·07	113·88	35·13
27	27·01	275·54	25·73	...	18·79	113·82	35·72
29	27·22	276·02	25·77	38·55	18·50	113·76	36·26
31	27·45	276·53	25·80	...	18·21	113·71	36·77
June 2	27·70	277·08	25·83	...	17·91	113·66	37·25
4	27·95	277·66	25·85	...	17·61	113·62	37·70
6	28·22	278·29	25·86	40·18	17·30	113·58	38·11
8	28·52	278·97	25·87	...	16·98	113·54	38·50
10	28·82	279·67	25·87	...	16·66	113·50	38·86
12	29·12	280·40	25·86	...	16·33	113·46	39·20
14	29·44	281·15	25·85	41·22	16·00	113·42	39·5
16	29·76	281·93	25·84	...	15·66	113·37	39·79
18	30·08	282·74	25·82	...	15·32	113·33	40·05
20	30·41	283·58	25·79	...	14·97	113·28	40·29
22	30·75	284·43	25·75	41·83	14·61	113·24	40·51
24	31·10	285·31	25·69	...	14·25	113·20	40·71
26	31·46	286·23	25·61	...	13·88	113·15	40·89
28	31·82	287·17	25·51	...	13·51	113·11	41·05
30	32·19	288·16	25·40	41·98	13·14	113·06	41·19
July 2	32·55	289·18	25·29	...	12·76	113·02	41·32
4	32·91	290·20	25·17	...	12·37	112·96	41·43
6	33·27	291·23	25·04	...	11·98	112·89	41·52
8	33·62	292·26	24·90	41·78	11·59	112·81	41·61
10	33·97	293·31	24·75	...	11·19	112·72	41·68
12	34·31	294·37	24·59	...	10·79	112·63	41·73
14	34·65	295·45	24·42	...	10·39	112·53	41·77
16	34·98	296·55	24·25	41·39	9·98	112·43	41·80
18	35·31	297·67	24·07	...	9·56	112·32	41·82
20	35·63	298·80	23·87	...	9·14	112·20	41·82
22	35·94	299·94	23·65	...	8·72	112·07	41·82
24	36·24	301·09	23·41	40·77	8·29	111·94	41·81
26	36·53	302·25	+23·16	...	+7·86	111·80	41·78

Greenwich Noon. 1903.	⊙	Light Time.	Appar. Diam.	Defect of Illumination.	Central Meridian.	Passage of Zero Meridian	
	°	m	″	″	°	h m	h m
May 13	124·03	6·480	11·93	0·84	223·97	9 18·35	9 56·03
15	...	6·580	11·75	0·87	205·60	10 33·78	11 11·61
17	...	6·682	11·57	0·90	187·17	11 49·51	12 27·46
19	...	6·786	11·39	0·93	168·69	13 5·45	13 43·48
21	127·85	6·893	11·22	0·96	150·16	14 21·56	14 59·70
23	...	7·001	11·05	0·98	131·58	15 37·90	16 16·16
25	...	7·110	10·89	1·00	112·95	16 54·48	17 32·84
27	...	7·221	10·73	1·01	94·28	18 11·23	18 49·66
29	131·71	7·333	10·56	1·02	75·57	19 28·12	20 6·64
31	...	7·445	10·39	1·04	56·82	20 45·22	21 23·84
June 2	...	7·558	10·23	1·05	38·02	22 2·51	22 41·22
4	...	7·672	10·08	1·06	19·18	23 19·96	23 58·73
6	135·61	7·787	9·93	1·07	0·31	...	0 37·53
8	...	7·903	9·79	1·07	341·41	1 16·37	1 55·24
10	...	8·018	9·65	1·08	322·46	2 34·14	3 13·11
12	...	8·134	9·51	1·08	303·47	3 52·14	4 31·22
14	139·56	8·250	9·37	1·08	284·47	5 10·32	5 49·41
16	...	8·366	9·24	1·07	265·45	6 28·51	7 7·62
18	...	8·483	9·11	1·07	246·40	7 46·76	8 25·94
20	...	8·599	8·99	1·07	227·32	9 5·16	9 44·41
22	143·56	8·715	8·87	1·07	208·22	10 23·70	11 3·03
24	...	8·831	8·75	1·06	189·08	11 42·39	12 21·79
26	...	8 946	8·64	1·06	169·90	13 1·22	13 40·68
28	...	9 061	8·53	1·06	150·70	14 20·16	14 59·66
30	147·61	9·176	8·42	1·05	131·48	15 39·17	16 18·70
July 2	...	9·291	8·32	1·04	112·25	16 58·24	17 37·79
4	...	9·405	8·22	1·04	93·00	18 17·35	18 56·94
6	...	9·519	8·12	1·03	73·73	19 36 55	20 16·19
8	151·72	9·632	8·03	1·02	54·45	20 55·85	21 35·52
10	...	9·744	7·94	1·01	35·15	22 15·20	22 54·90
12	...	9·856	7·85	1·00	15·84	23 34·61	...
14	...	9·967	7·76	0·99	356·51	0 14·34	0 53·08
16	155·88	10·078	7·67	0·98	337·17	1 33·83	2 13·61
18	...	10·188	7·59	0·97	317·81	2 53·41	3 33·22
20	...	10·298	7·51	0·96	298·44	4 13·05	4 52·89
22	...	10·407	7·43	0·94	279·06	5 32·73	6 12·58
24	160·10	10·515	7·35	0·93	259·67	6 52·43	7 32·30
26	...	10·622	7·28	0·92	240·27	8 12·18	8 52·08

Greenwich Noon. 1903.	P.	L−O.	B.	A−L.	*B.*	Q.	E.
	°	°	°	°	°	c	°
May 13	26·12	273·55	+25·29	33·19	+20·64	114·39	30·80
15	26·18	273·68	25·36	...	20·39	114·29	31·63
17	26·26	273·87	25·43	...	20·14	114·19	32·41
19	26·37	274·11	25·50	...	19·88	114·10	33·15
21	26·50	274·40	25·56	36·26	19·62	114·01	33·85
23	26·65	274·73	25·62	...	19·35	113·94	34·51
25	26·82	275·11	25·68	...	19·07	113·88	35·13
27	27·01	275·54	25·73	...	18·79	113·82	35·72
29	27·22	276·02	25·77	38·55	18·50	113·76	36·26
31	27·45	276·53	25·80	...	18·21	113·71	36·77
June 2	27·70	277·08	25·83	...	17·91	113·66	37·25
4	27·95	277·66	25·85	...	17·61	113·62	37·70
6	28·22	278·29	25·86	40·18	17·30	113·58	38·11
8	28·52	278·97	25·87	...	16·98	113·54	38·50
10	28·82	279·67	25·87	...	16·66	113·50	38·86
12	29·12	280·40	25·86	...	16·33	113·46	39·20
14	29·44	281·15	25·85	41·22	16·00	113·42	39·5
16	29·76	281·93	25·84	...	15·66	113·37	39·79
18	30·08	282·74	25·82	...	15·32	113·33	40·05
20	30·41	283·58	25·79	...	14·97	113·28	40·29
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24	31·10	285·31	25·69	...	14·25	113·20	40·71
26	31·46	286·23	25·61	...	13·88	113·15	40·89
28	31·82	287·17	25·51	...	13·51	113·11	41·05
30	32·19	288·16	25·40	41·98	13·14	113·06	41·19
July 2	32·55	289·18	25·29	...	12·76	113·02	41·32
4	32·91	290·20	25·17	...	12·37	112·96	41·43
6	33·27	291·23	25·04	...	11·98	112·89	41·52
8	33·62	292·26	24·90	41·78	11·59	112·81	41·61
10	33·97	293·31	24·75	...	11·19	112·72	41·68
12	34·31	294·37	24·59	...	10·79	112·63	41·73
14	34·65	295·45	24·42	...	10·39	112·53	41·77
16	34·98	296·55	24·25	41·39	9·98	112·43	41·80
18	35·31	297·67	24·07	...	9·56	112·32	41·82
20	35·63	298·80	23·87	...	9·14	112·20	41·82
22	35·94	299·94	23·65	...	8·72	112·07	41·82
24	36·24	301·09	23·41	40·77	8·29	111·94	41·81
26	36·53	302·25	+23·16	...	+7·86	111·80	41·78

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	°	m	″	″	°	h m	h m
May 13	124·03	6·480	11·93	0·84	223·97	9 18·35	9 56·03
15	...	6·580	11·75	0·87	205·60	10 33·78	11 11·61
17	...	6·682	11·57	0·90	187·17	11 49·51	12 27·46
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21	127·85	6·893	11·22	0·96	150·16	14 21·56	14 59·70
23	...	7·001	11·05	0·98	131·58	15 37·90	16 16·16
25	...	7·110	10·89	1·00	112·95	16 54·48	17 32·84
27	...	7·221	10·73	1·01	94·28	18 11·23	18 49·66
29	131·71	7·333	10·56	1·02	75·57	19 28·12	20 6·64
31	...	7·445	10·39	1·04	56·82	20 45·22	21 23·84
June 2	...	7·558	10·23	1·05	38·02	22 2·51	22 41·22
4	...	7·672	10·08	1·06	19·18	23 19·96	23 58·73
6	135·61	7·787	9·93	1·07	0·31	...	0 37·53
8	...	7·903	9·79	1·07	341·41	1 16·37	1 55·24
10	...	8·018	9·65	1·08	322·46	2 34·14	3 13·11
12	...	8·134	9·51	1·08	303·47	3 52·14	4 31·22
14	139·56	8·250	9·37	1·08	284·47	5 10·32	5 49·41
16	...	8·366	9·24	1·07	265·45	6 28·51	7 7·62
18	...	8·483	9·11	1·07	246·40	7 46·76	8 25·94
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22	143·56	8·715	8·87	1·07	208·22	10 23·70	11 3·03
24	...	8·831	8·75	1·06	189·08	11 42·39	12 21·79
26	...	8 946	8·64	1·06	169·90	13 1·22	13 40·68
28	...	9 061	8·53	1·06	150·70	14 20·16	14 59·66
30	147·61	9·176	8·42	1·05	131·48	15 39·17	16 18·70
July 2	...	9·291	8·32	1·04	112·25	16 58·24	17 37·79
4	...	9·405	8·22	1·04	93·00	18 17·35	18 56·94
6	...	9·519	8·12	1·03	73·73	19 36 55	20 16·19
8	151·72	9·632	8·03	1·02	54·45	20 55·85	21 35·52
10	...	9·744	7·94	1·01	35·15	22 15·20	22 54·90
12	...	9·856	7·85	1·00	15·84	23 34·61	...
14	...	9·967	7·76	0·99	356·51	0 14·34	0 53·08
16	155·88	10·078	7·67	0·98	337·17	1 33·83	2 13·61
18	...	10·188	7·59	0·97	317·81	2 53·41	3 33·22
20	...	10·298	7·51	0·96	298·44	4 13·05	4 52·89
22	...	10·407	7·43	0·94	279·06	5 32·73	6 12·58
24	160·10	10·515	7·35	0·93	259·67	6 52·43	7 32·30
26	...	10·622	7·28	0·92	240·27	8 12·18	8 52·08

being +0°·08 in R.A., −0°·05 in N.P.D. Struve's results include a correction for the precessional movement of *Mars'* equator, the annual recession of the point O on its orbit being 7″·07. I did not, however, note this point in time to introduce the correction in the present ephemeris, but hope to do so in future years. The effect on L—O is only about 0°·04, which is practically negligible.

P denotes the position angle of the axis of *Mars*; L—O+180° the right ascension of the Earth referred to the plane of *Mars'* equator, and reckoned from O, the point of the vernal equinox of *Mars'* northern hemisphere; Λ—O+180° the corresponding quantity for the Sun; B B the declinations of the Earth and Sun, reckoned from the plane of *Mars'* equator; Q the position angle of the greatest defect of illumination; q the amount of the same; E the areocentric angle between the Earth and Sun.

Thus Λ—L is the angle between the meridians of *Mars* which are central to the Earth and to the Sun; the point where an image of the Sun should be looked for is distant ½(Λ—L) in longitude from the centre of the disc, on the side towards the fully illuminated limb, and is in areocentric latitude ½(B+B).

⊙ is the areocentric longitude of the Sun referred to the plane of *Mars'* orbit, and reckoned from O (defined above). This column gives at once the season on *Mars*; ⊙ = 0° corresponds to March 20 on the Earth, ⊙ = 30° to April 20, and so on.

In accordance with more than one suggestion sent to me, I have altered the value of the diameter of the planet at distance unity from 9″·60 to 9″·30. This is the absolute diameter deduced by Dr. See from a discussion of all the available material. It requires to be increased by the irradiation correction, but as that varies with the size and quality of the telescope, it is better to leave it to the observers to apply the correction. The value used in the *Nautical Almanac* is 9″·36.

The zero meridian and period of rotation have been carried on unchanged from Mr. Marth's last ephemeris, the assumed sidereal rotation in 24^h of mean time being 350°·89202; the equivalent period of sidereal rotation is $24^h\ 37^m\ 22^s{\cdot}654$ of mean time.

In response to my request for observations of transits of spots across the central meridian, Mr. Lowell has sent me the following observations of the transit of *Fastigium Aryn*:—

Observed G.M.T. of Transit.				Earlier than Ephemeris.	Weight.
1901.	d	h	m	m	
May	4	14	30	8	5
	8	17	3	10	2
June	9	13	15	16	2
	10	14	3	8	2
July	18	14	35	15	2

From which he deduces that the ephemeris' time was too late by $10^m{\cdot}5$.

I quote his own words as regards the method of observation :—

"These transits were got by setting the micrometer wire parallel to the direction of the axis as given in the ephemeris, and then noting the moment at which the snow-cap and the marking were equidistant from it.

"In order to determine whether the snow-cap itself were eccentrically placed with regard to the pole, I measured its position angle at various longitudes, the preliminary result of which shows its centre to be very close indeed to the pole—within less than half a degree distant. The result gives 0°·32 for its deviation in the direction of the meridian of 90°–270°, so that even this amount would delay, not hasten, the transit of the zero meridian. Consequently the position of the snow-cap will not explain the action, which would seem to be due to error in the epoch or the rotation period, or both."

With regard to this discordance I would point out that Mr. Marth in his last ephemeris altered his zero meridian to agree with Mr. Lowell's observations of 1894, so that we have only the effect of seven years' rotation to consider.

Now the adopted period can scarcely be in error by more than $0^{s}\cdot07$, or twenty-five seconds per annum ; this would only amount to three minutes in seven years.

From the method of Mr. Lowell's observations any error in the angle P would affect the time of transit ; so that if his discordance of 10^{m} is real, I think that the larger portion of it is probably due to error in the assumed position of *Mars'* axis.

M. Antoniadi has communicated to me some observations of the transit of the preceding edge of *Mare Acidalium* across the central meridian, from which he concludes that the error of my ephemeris was inappreciable. I have therefore not considered the evidence sufficiently strong to make any alteration in my constants ; but those who desire can adapt the ephemeris approximately to Mr. Lowell's observations by adding 2°·5 to the central meridian and subtracting 11^{m} from the transit of zero meridian. I may mention that the second decimal place in this last column has no pretence to accuracy, and is merely inserted to diminish cumulative error in the interpolation.

Benvenue, 55 *Ulundi Road, Blackheath, London, S.E.:*
1902 *June* 3.

Erratum in Annual Report.

On p. 314, vol. lxii. *Monthly Notices*, line 8, *for* Roberts *read* Innes.

Errata in Cape Double Star Results, Monthly Notices, vol. lxii.

Page		*For*	*Read*
476	$12^h\ 10^m$	334°·0	344°·0
	13 53	Remark 4	Remark 64
478	*h* 5069	AC	AB, C
479	Sellors	3°·35	335°
	No. 3	−57°	−58°
481	No. 92	83°	183°
482	1901·07	5–4	6–5
484	19^h No. 18	18	21

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXII. SUPPLEMENTARY NUMBER, 1902. NO. 9

On the General Solution of Laplace's Equation and the Equation of Wave Motions, and on an undulatory explanation of Gravity. By E. T. Whittaker, M.A.

1. *Laplace's Equation.*

The first part of this communication is concerned with the well-known equation which was first introduced in Laplace's memoir on the ring of *Saturn*, and which is now of such importance in mathematical physics. The general solution has not hitherto been found in a finite form: we shall show that it is given in a finite form by the following result:

The general solution of Laplace's equation

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}+\frac{\partial^2 V}{\partial z^2}=0$$

is

$$V=\int_0^{2\pi} f(x\cos v+y\sin v+iz,\ v)\,dv,$$

where f is an arbitrary function of the two arguments $x\cos v+y\sin v+iz$ and v.

To establish this, let V (x, y, z) be any solution (single-valued or many-valued) of Laplace's equation. Since the differential equation is unaffected by a change of origin, and since any function of the two arguments $(x\cos v+y\sin v+iz)$ and v is also a function of the arguments $(x'\cos v+y'\sin v+iz')$ and v, where (x', y', z') are the coordinates of the point (x, y, z) referred to parallel axes through any other origin, it clearly will not affect the generality of the proof if any particular point be taken as origin; we shall therefore suppose that the origin is taken at some point at which some branch of the function V (x, y, z) is

regular, so that this branch of V (x, y, z) can be expanded in the neighbourhood of the origin in the form

$$V(x, y, z) = a_0 + a_1x + b_1y + c_1z + a_2x^2 + b_2y^2 + c_2z^2 + d_2yz + e_2zx + f_2xy + a_3x^3 + \ldots,$$

where a_0, a_1, b_1, ... are constants, and the series is absolutely and uniformly convergent for a domain of finite extent.

Substituting this expansion in Laplace's equation, and equating to zero the coefficients of the various powers of x, y, and z, we obtain an infinite number of linear relations between the constants a_0, a_1, b_1, ... There are $\frac{1}{2}n(n-1)$ of these relations between the $\frac{1}{2}(n+1)(n+2)$ coefficients of the terms of any degree n in the expansion of V; so that only $\{\frac{1}{2}(n+1)(n+2) - \frac{1}{2}n(n-1)\}$ or $(2n+1)$ of the coefficients of terms of degree n in the expansion of V are really independent.

Moreover, it is clear that the terms of degree n in V must satisfy Laplace's equation, quite independently of the terms of other degrees; and therefore the terms of degree n in V must be a linear combination of $(2n+1)$ linearly independent solutions of degree n.

To find these solutions, consider the expansion of the quantity $(x \cos v + y \sin v + iz)^n$ as a sum of sines and cosines of multiples of v, in the form

$$(x \cos v + y \sin v + iz)^n = g_0(x, y, z) + g_1(x, y, z) \cos v + g_2(x, y, z) \cos 2v + \ldots + g_n(x, y, z) \cos nv + h_1(x, y, z) \sin v + h_2(x, y, z) \sin 2v + \ldots + h_n(x, y, z) \sin nv.$$

The $(2n+1)$ quantities $g(x, y, z)$ and $h(x, y, z)$ are clearly linearly independent homogeneous polynomials of degree n in x, y, z; and each of them must satisfy Laplace's equation, since $(x \cos v + y \sin v + iz)^n$ does so. These are therefore the $(2n+1)$ independent solutions of Laplace's equation, of degree n.

Now since by Fourier's theorem we have the relations

$$g_m(x, y, z) = \frac{1}{\pi}\int_0^{2\pi} (x \cos v + y \sin v + iz)^n \cos mv \, dv$$

$$h_m(x, y, z) = \frac{1}{\pi}\int_0^{2\pi} (x \cos v + y \sin v + iz)^n \sin mv \, dv,$$

it follows that each of these $(2n+1)$ solutions can be expressed in the form

$$\int_0^{2\pi} f(x \cos v + y \sin v + iz, v) \, dv,$$

and therefore any linear combination of these $(2n+1)$ solutions can be expressed in this form. That is, the terms of degree n in V (x, y, z) can be expressed in this form, where n is any positive integer; and therefore V (x, y, z) (which was taken to be *any* solution of Laplace's equation) is itself of this form; which establishes the theorem.

2. *The Partial Differential Equation of Wave-Motions.*

It can in the same way be shown that the *general solution of the general differential equation of wave-motions, namely*

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}+\frac{\partial^2 V}{\partial z^2}=k^2\frac{\partial^2 V}{\partial t^2}$$

is

$$V=\int_0^{\pi}\int_0^{2\pi} f\,(x\sin v\cos\psi+y\sin v\sin\psi+z\cos v+kt,\ v,\ \psi)\,dv\,d\psi,$$

where f is an arbitrary function of the three arguments

$$x\sin v\cos\psi+y\sin v\sin\psi+z\cos v+kt,\ v,\ \text{and}\ \psi.$$

From this result it follows, by the application of Fourier's double-integral theorem, that *any solution of the equation*

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}+\frac{\partial^2 V}{\partial z^2}=k^2\frac{\partial^2 V}{\partial t^2}$$

can be analysed into simple plane waves.

3. *An Undulatory Explanation of Gravity.*

In connection with the last property it can be shown that *distributions of simple waves exist such that, although each individual wave is periodic with respect to the time, yet the total disturbance at any point does not vary with the time.* The simplest example of this is the following. Suppose a particle to be emitting spherical waves, such that the disturbance due to the waves whose wave-length lies between $\frac{2\pi}{\mu}$ and $\frac{2\pi}{\mu+d\mu}$ is

$$\frac{2d\mu}{\pi\mu}\cdot\frac{\sin\mu(Vt-r)}{r},$$

where V is the velocity of propagation of the waves. Then after the waves have reached the point r, so that $(Vt-r)$ is positive, the total disturbance there (due to the sum of all the waves) is

$$\frac{2}{\pi r}\int_0^{\infty}\frac{\sin\mu(Vt-r)}{\mu}\,d\mu$$

or

$$\frac{2}{\pi r}\int_0^{\infty}\frac{\sin y}{y}\,dy,\quad \text{where } \mu(Vt-r)=y,$$

or

$$\frac{1}{r},$$

i.e. the disturbance is independent of the time and is everywhere proportional to the gravitational potential of the particle. It is easily seen that *for all such distributions the total disturbance can always be represented by a solution of Laplace's equation.*

Since Laplace's equation is the equation satisfied by the components of any field of force due to gravitating bodies, this result suggests an explanation of the propagation of gravitation. For we thus see that it is possible to analyse the field of force due to a gravitating body, by a "spectrum analysis" as it were, into an infinite number of constituent fields; and although the whole field of force does not vary with the time, yet each of the constituent fields is of an undulatory character, *i.e.* the disturbance at any point reproduces itself after the lapse of any time at another point whose distance is proportional to the elapsed time. But this result assimilates the propagation of gravitation to that of light; for the undulatory phenomena just described, in which the varying vector is a gravitational force perpendicular to the wave-front, may be compared with those made familiar by the electromagnetic theory of light, in which the varying vectors consist of electric and magnetic forces parallel to the wave-front. The waves are in other respects of the same type in the two cases, and it seems probable that an identical property of the medium ensures their transmission through space. This undulatory theory of gravity would require that gravity should be propagated with a finite velocity, which, however, need not be the same as that of light, and may be enormously greater.

Of course this investigation does not explain the *cause* of gravity; all that is done is to show that the propagation across space of forces which vary as the inverse square of the distance does not require for its explanation any other property of the medium than one which has long been known and accepted.

On the Mean Distance of a Planet, as a Function of Three Heliocentric Distances and the Observed Times. By Shin Hirayama.

§ 1. Let r_1, r_2, r_3 be three heliocentric distances of a planet;
t_1, t_2, t_3 the corresponding observed times;
a the mean distance.

The radius vector of a planet must satisfy the differential equation

$$\frac{d^2s}{dt^2} - \frac{2}{\sqrt{s}} + \frac{2}{a} = 0,$$

putting $r^2 = s$.

If we let

$$\theta_1 = k(t_3 - t_2),\ \theta_2 = k(t_3 - t_1),\ \theta_3 = k(t_2 - t_1),\ \log k = 8{\cdot}235581 - 10,$$

and express the value r^2 in terms of t by expansion into series, we have

$$s = r^2 = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4,$$

where a_0 a_1, a_2, a_3, a_4 are five constants independent of time.

Now, for $t = -\theta_3$

$$s = s_1, \quad \frac{d^2s}{dt^2} = \frac{2}{\sqrt{s_1}} - \frac{2}{a},$$

for $t = 0$

$$s = s_2, \quad \frac{d^2s_2}{dt^2} = \frac{2}{\sqrt{s_2}} - \frac{2}{a},$$

for $t = \theta_1$

$$s = s_3, \quad \frac{d^2s_3}{dt^2} = \frac{2}{\sqrt{s_3}} - \frac{2}{a}.$$

Hence

$$s_1 = a_0 - \theta_3 a_1 + \theta_3^2 a_2 - \theta_3^3 a_3 + \theta_3^4 a_4,$$

$$s_2 = a_0,$$

$$s_3 = a_0 + \theta_1 a_1 + \theta_1^2 a_2 + \theta_1^3 a_3 + \theta_1^4 a_4,$$

$$\frac{2}{\sqrt{s_1}} - \frac{2}{a} = 2a_2 - 6\theta_3 a_3 + 12\theta_3^2 a_4,$$

$$\frac{2}{\sqrt{s_2}} - \frac{2}{a} = 2a_2,$$

$$\frac{2}{\sqrt{s_3}} - \frac{2}{a} = 2a_2 + 6\theta_1 a_3 + 12\theta_1^2 a_4.$$

Eliminating the five constants a_0, a_1, a_2, a_3, a_4 from these six equations, we get a single equation of the form

$$\left.\begin{aligned} &\frac{\theta_1\theta_2\theta_3}{a} = 2\left(\frac{\theta_1\mu_1}{r_1} + \frac{\theta_2\mu_2}{r_2} + \frac{\theta_3\mu_3}{r_3}\right) = (\theta_1 r_1^2 - \theta_2 r_2^2 + \theta_3 r_3^2) \\ &\text{where} \\ &\mu_1 = \frac{1}{12}(\theta_2\theta_3 - \theta_1^2), \ \mu_2 = \frac{1}{12}(\theta_1\theta_3 + \theta_2^2), \ \mu_3 = \frac{1}{12}(\theta_1\theta_2 - \theta_3^2) \end{aligned}\right\} \quad (1)$$

This is the required equation. A less exact formula is given by Radau in *Bulletin Astronomique*, tome ii. p. 11.

§ 2. For the purpose of testing the above expression (1) I have chosen the *Ceres* example treated by Gauss, Oppolzer, and Gibbs, the interval of extreme observations being about 260 days.

$\log \theta_1 = 0{\cdot}335852$	$\log \mu_1 = 9{\cdot}669211$	$\log r_1 = 0{\cdot}428279$
$\log \theta_2 = 0{\cdot}650362$	$\log \mu_2 = 0{\cdot}318372$	$\log r_2 = 0{\cdot}413281$
$\log \theta_3 = 0{\cdot}362407$	$\log \mu_3 = 9{\cdot}562392$	$\log r_3 = 0{\cdot}406200$

The computation by (1) gives us $\log a = 0{\cdot}442438$,
while Oppolzer gives $\log a = 0{\cdot}442463$.

The coincidence is fairly good, if we consider the long interval of time between two observations.

§ 3. In the special case of parabolical orbits (1) becomes

$$\theta_1 r_1^{\frac{3}{2}}\left(1-\frac{2\mu_1}{r_1^3}\right)-\theta_2 r_2^{\frac{3}{2}}\left(1+\frac{2\mu_2}{r_2^3}\right)+\theta_3 r_3^{\frac{3}{2}}\left(1-\frac{2\mu_3}{r_3^3}\right)=0 \qquad (2)$$

—a relation between three heliocentric distances and the time.

§ 4. Let E_1, E_2, E_3 be the corresponding excentric anomalies, then we have

$$(r_1-a)\sin(E_3-E_2)-(r_2-a)\sin(E_3-E_1)+(r_3-a)\sin(E_2-E_1)=0,$$

while (1) may be written in the form

$$(r_1-a)\theta_1\left(r_1+a+\frac{2\mu_1}{ar_1}\right)-(r_2-a)\theta_2\left(r_2+a-\frac{2\mu_2}{ar_2}\right)+(r_3-a)\theta_3\left(r_3+a+\frac{2\mu_3}{ar_3}\right)=0.$$

Hence, comparing the two above equations, we see that

$$\sin(E_3-E_2) \qquad \sin(E_3-E_1) \qquad \sin(E_2-E_1)$$

are respectively proportional to

$$\theta_1\left(r_1+a+\frac{2\mu_1}{ar_1}\right) \quad \theta_2\left(r_2+a-\frac{2\mu_2}{ar_2}\right) \quad \theta_3\left(r_3+a+\frac{2\mu_3}{ar_3}\right)=0.$$

Observations of the Satellite of Neptune from Photographs taken at the Royal Observatory, Greenwich, between 1902 *January* 6, *and April* 10.

(*Communicated by the Astronomer Royal.*)

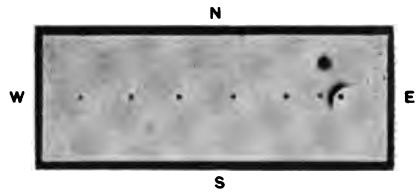
The following measures of position-angle and distance of *Neptune's* satellite were made from photographs taken with the 26-inch refractor of the Thompson equatorial. The occulting shutter was generally used, and the position of the plate adjusted so that the planet was behind the shutter while the satellite was just outside of it. By means of the shutter, which is pivoted (see *Monthly Notices*, vol. lx. No. 7), short exposures were given at intervals to the planet. Rapid plates were used, and the exposures given to the satellite were from 10^m to 30^m, generally 20^m. For the planet the short exposures, which may be taken as about $\frac{1}{10}^s$ in duration, were given each half-minute. Thus to an exposure of 20^m on the satellite there would be thirty-nine of these short exposures on the planet.

The zero of position-angle was obtained by stopping the clock and giving a short supplementary exposure. Generally, several short exposures were given, the clock being stopped for a short time between each of them, so that each photograph contains, in

ROYAL OBSERVATORY, GREENWICH.

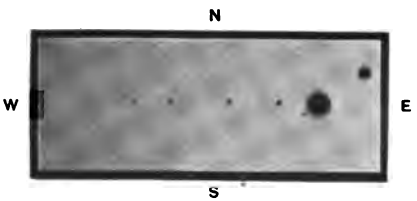
PHOTOGRAPHS OF NEPTUNE AND SATELLITE TAKEN WITH THE THOMPSON 26-INCH PHOTOGRAPHIC REFRACTOR.

Enlarged five times. Scale 1 mm. = 6″.

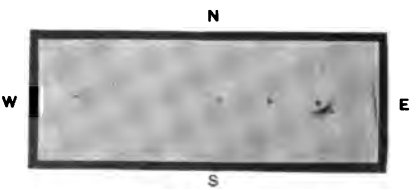


1902 February 11. *Neptune* to the right under the occulting shutter within the halo of the secondary spectrum. The satellite is to the left of *Neptune* (position-angle 277°). The other images are with five exposures of four seconds each on *Neptune* for orientation—the telescope being displaced in R.A. between the exposures.

The star north-west of *Neptune* is B.D. +22° 1138. Mag. 9·3.



1902 February 12. *Neptune* not occulted. Position-angle of satellite 235°. The other images are with exposures of 5^s, 4^s, 3^s and 5^s on *Neptune* (starting from *Neptune*).



1902 March 3. *Neptune* occulted. Position-angle of satellite 125°. The other images are with exposures of 5^s, 3^s, 2^s, 2^s and 3^s on *Neptune*. It will be seen that the image of the satellite with 20^m exposure is nearly equivalent to that of *Neptune* with 3^s exposure.

addition to the long-exposure photograph of the satellite, a of number short-exposure images of *Neptune*.

On some of the photographs the duration of the supplementary exposures was adjusted so as to give images of the planet of the same size and density as the image of the satellite. Incidentally these determine the length of exposure given with the occulting shutter, but they are of photometric importance as showing that the satellite requires an exposure 420 times that of *Neptune* to give an equal photographic image, which, on the assumption that the photographic effect is the same for the same total amount of light, makes the satellite $6^m \cdot 55$ fainter than *Neptune*.

The following table gives the details of these observations :—

No of Plate.	Date.	Exposure of Satellite.	Exposure of Planet giving an Equal Image.	Ratio.	Log.	Diff. of Magnitude.
	1902.	m	s			
1106	Feb. 12	20	2·9	414	2·617	6·54
1115	Feb. 28	21	2·7	467	·669	6·67
1119	Mar. 3	20	3·0	400	·602	6·51
1120	Mar. 3	15	2·5	360	·556	6·39
		20	3·0	400	·602	6·51
1121	Mar. 3	20	2·5	480	·681	6·70
			Mean	420	2·621	6·55

The photographs were measured in a position micrometer in direct and reversed positions by Mr. Dyson, Mr. Davidson, and Mr. Melotte, and the results obtained by each measurer are given in order to show the degree of accordance obtained.

Corrections have not been applied separately to the distances or angles for refraction. These will in all cases be less than $0''\cdot01$. The mean effects of refraction and aberration have, however, been included in the adopted value of the scale, as these corrections affect the mean distance of the satellite slightly, and would directly affect the mass of *Neptune* determined from these observations.

The value of 1^{rev} of the screw of the measuring micrometer was determined in terms of a réseau interval of one of Gautier's réseaux used in photographic work with the Thompson and Astrographic equatorials. For photographs with the Thompson equatorial cleared of the effect of differential refraction and aberration the réseau interval $= 150''\cdot89$. The correction for differential refraction on these photographs of *Neptune* varies from $+''\cdot042$ to $+''\cdot072$, and for differental aberration from $+0''\cdot006$ to $+''\cdot010$. A mean total correction of $+''\cdot07$ has been adopted, giving the réseau interval $= 150''\cdot96$, and has been used for all the photographs.

The tabular positions were computed from the data given in the *Connaissance des Temps*, based on M. H. Struve's elements, the eccentricity of the orbit being neglected owing to the uncertainty as to the present position of the periastron.

Neptune and Satellite.

Position-angle and Distance, from Photographs taken with the 26-inch Refractor.

Date. 1902.				Position-angle.						Distance.						Exposure.	Remarks.
	d	h	m	s	D.	C.D.	P.M.	Mean.	Tab.	T−O.	D.	C.D.	P.M.	Mean.	Tab.	T−O.	m	
Jan.	6	11	14	13	306°46	305°53	304°35	305°45	307°41	+1°96	12″77	13″04	13″04	12″95	12″83	−0″12	20	Neptune not occulted.
	6	12	14	53	304 86	303·82	306·22	304·97	304·60	−0·37	12·65	12·81	12·83	12·76	13 09	+0·33	20½	
	14	11	36	56	196·58	196 14	195·40	196·04	197·33	+1·29	11·20	11·11	10·98	11·10	11·49	+0·39	25	
	14	12	4	48	194·45	195·06	194·87	194·79	195·65	+0·86	11·21	11·44	11·38	11·34	11·40	+0·06	20	Neptune not occulted.
	24	9	7	14	289·11	288·67	288·27	288·68	290·52	+1·84	14·21	14·29	14·16	14·22	14·48	+0·26	20½	
	24	9	36	34	289 60	288·38	287·65	288·54	289·46	+0 92	14·60	14·76	14·71	14·69	14·61	−0 08	20	Neptune not occulted.
	28	12	7	23	58·82	59·00	59·50	59·11	59 80	+0·69	15 46	15·40	15·07	15·31	15·43	+0·12	21	
	28	12	35	39	57·00	57·80	57·19	57·33	58 86	+1·53	14·51	14·75	14·51	14·59	15·32	−0·27	21	Neptune not occulted. Windy.
	29	10	37	6	351·52	352·70	351·62	351·95	353·30	+1·35	10·63	10·65	10·48	10 59	10·75	+0·16	30	
	29	11	15	6	348·70	349·25	347 01	348·32	350·77	+2·45	10·80	10·63	10·86	10·76	10·75	−0·01	34	Neptune not occulted.
	30	9	16	58	282·75	282·39	282·26	282·47	283·98	+1·51	15·11	15·35	15·27	15·24	15·18	−0·06	25	
	31	8	8	53	244·58	243·96	244·83	244·46	244·48	+0·02	15·98	16·25	16·10	16·11	15·90	−0 21	25	
Feb.	10	8	55	20	336·17	335·37	337·38	336·31	336 90	+0·59	11·21	10·86	10·85	10·97	10·86	−0 11	6	
	10	9	20	48	333·57	332·97	334·33	333·62	335·25	+1·63	10·79	10·98	11·08	10·95	10·91	−0·04	10	

Date. 1902.				Position-angle.						Distance.						Exposure.	Remarks.
				D.	C.D.	P.M.	Mean.	Tab.	T−O.	D.	C.D.	P.M.	Mean.	Tab.	T−O.		
	d	h	m	s	°	°	°	°	°	″	″	″	″	″	″	m	
Feb.	11	7	9	16	277·08	276·23	276·30	276·54	276·77	+0·23	15·86	15·89	15·87	15·87	15·83	−0·04	20	
	11	7	37	24	274·13	274·40	274·32	274·28	275·92	+1·64	15·67	15·83	15·95	15·82	15·91	+0·09	20	
	11	8	11	9	274·22	274·07	274·00	274·10	274·90	+0·80	16·10	15·99	15·84	15·98	16·01	+0·03	20½	
	11	8	39	21	273·75	273·85	273·72	273·77	274·08	+0·31	16·09	16·06	15·95	16·03	16·08	+0·05	20	
	12	7	51	5	233·48	233·12	232·25	232·95	233·50	+0·55	14·57	14·71	14·99	14·76	14·65	−0·11	20	
	13	8	13	25	151·67	151·43	152·95	152·02	153·93	+1·91	10·92	10·53	10·54	10·66	10·94	+0·28	30	Satellite badly defined.
	15	8	2	34	49·11	49·18	48·80	49·03	49·87	+0·84	14·18	13·89	13·88	13·98	14·22	+0·24	30	
	15	9	3	39	47·00	46·06	49·04	47·37	47·55	+0·18	13·73	13·56	13·92	13·74	13·95	+0·21	20	Satellite badly defined.
	16	7	5	31	330·15	329·62	329·92	329·90	332·68	+2·78	11·14	10·59	10·78	10·84	10·96	+0·12	20	Satellite badly defined.
	16	8	19	44	326·27	325·88	326·78	326·31	328·08	+1·77	11·16	11·25	10·91	11·11	11·14	+0·03	20½	
	28	7	59	1	309·30	309·10	308·96	309·12	309·68	+0·56	12·10	12·37	12·33	12·27	12·23	−0·04	21	
	28	8	48	39	308·08	307·13	308·56	307·92	307·25	−0·67	11·97	12·15	12·00	12·04	12·44	+0·40	20	
	28	9	26	28	305·73	304·88	305·43	305·35	305·45	+0·10	12·47	12·58	12·32	12·46	12·60	+0·14	20	
Mar.	1	8	27	0	258·13	257·30	257·88	257·77	259·57	+1·80	16·60	16·33	16·28	16·40	16·55	+0·15	21	
	3	7	19	54	125·72	126·46	126·45	126·21	127·27	+1·06	12·59	12·58	12·60	12·59	12·41	−0·18	20	
	3	8	5	20	124·65	124·08	124·75	124·49	125·12	+0·63	12·59	12·67	12·61	12·62	12·61	−0·01	15	
	3	8	29	1	122·57	123·22	123·03	122·94	124·02	+1·08	12·58	12·63	12·59	12·60	12·71	+0·11	20	
	3	9	6	0	121·20	121·29	121·56	121·35	122·33	+0·98	12·53	12·73	12·59	12·62	12·87	+0·25	20	
	3	9	34	45	121·12	121·04	120·74	120·97	121·05	+0·08	13·12	13·08	12·90	13·03	13·00	−0·03	20	

Date. 1902.				Position-angle.						Distance.						Exposure.	Remarks.
				D.	C.D.	P.M.	Mean.	Tab.	T−O.	D.	C.D.	P.M.	Mean.	Tab.	T−O.		
	d	h	m	s	°	°	°	°	°	°	"	"	"	"	"	"	m	
Mar.	17	9	49	44	357·08	356·23	355·62	356·31	358·54	+2·23	10·64	10·72	10·78	10·71	10·54	−0·17	20	Satellite in the glare of Neptune.
	19	7	59	16	245·35	245·10	245·33	245·26	245·48	+0·22	15·41	15·52	15·59	15·51	15·66	+0·15	10	
	19	8	24	43	244·17	244·42	244·32	244·30	244·72	+0·42	15·28	15·22	15·30	15·27	15·59	+0·32	10	
	19	8	52	16	242·92	243·37	243·15	243·15	243·89	+0·74	15·11	15·28	15·67	15·35	15·51	+0·16	10	
	21	8	6	21	102·73	102·70	103·68	103·04	104·17	+1·13	14·73	15·01	14·94	14·89	14·72	−0·17	12	
	21	8	35	26	102·80	103·17	103·26	103·08	103·20	+0·12	14·62	14·74	14·69	14·68	14·82	+0·14	12	
	21	9	16	6	100·07	100·67	100·51	100·42	101·87	+1·45	14·72	14·73	14·46	14·64	14·97	+0·33	12	
	22	9	25	4	59·37	59·65	59·61	59·54	60·13	+0·59	14·86	14·95	14·80	14·87	15·10	+0·23	12	
	25	6	57	55	239·65	239·69	239·31	239·55	241·99	+2·44	15·04	15·08	15·12	15·08	15·26	+0·18	20½	
	25	8	32	38	238·47	238·44	238·80	238·57	238·98	+0·41	14·75	14·85	14·87	14·82	14·95	+0·13	20	
	25	9	4	3	237·38	237·93	237·68	237·66	237·95	+0·29	14·97	14·92	15·06	14·98	14·84	−0·14	20	
	27	7	58	25	99·98	99·52	99·07	99·52	98·74	−0·78	14·77	15·10	15·05	14·97	15·25	+0·28	12	Satellite very faint.
	27	8	19	55	96·18	96·28	95·23	95·90	98·07	+2·17	15·67	15·60	15·52	15·60	15·31	−0·29	12	Satellite very faint.
	27	8	46	45	96·22	96·66	96·35	96·41	97·25	+0·84	15·54	15·53	15·77	15·61	15·40	−0·21	20	
	27	9	13	9	95·58	95·50	95·77	95·62	96·45	+0·83	15·66	15·55	15·22	15·48	15·47	−0·01	20	
Apr.	6	8	1	49	227·03	227·28	227·40	227·24	227·60	+0·36	13·47	13·31	13·22	13·33	13·57	+0·24	20	
	10	8	11	37	319·50	319·25	318·75	319·17	319·76	+0·59	11·07	10·98	11·03	11·03	11·26	+0·23	15	
	10	8	37	35	317·01	316·63	316·36	316·67	318·31	+1·64	11·20	11·21	11·10	11·17	11·35	+0·18	15	

Observation of Saturn on 1902 *July* 17, *made at Perth Observatory, Western Australia.*

(*Communicated by W. Ernest Cooke, M.A., Government Astronomer.*)

As astronomers have been asked for observations of *Saturn* about July 17, I beg to report as follows :—

July 17 between 0^h and 1^h G.M.T. Definition remarkably good. Instrument, 10-inch guide telescope of astrograph. Power of eyepiece not measured but estimated about 600. The division could be distinctly traced across the planet, with no sign of a break.

This was the only chance we had, the weather on each side being cloudy or definition bad.

The north polar regions were very dark.

1902 *July* 21.

Observations of Comet Tempel 2, 1899 IV., at the Radcliffe Observatory, Oxford.

(*Communicated by A. A. Rambaut, D.Sc., F.R.S., Radcliffe Observer.*)

The following observations were made with the 10-inch Barclay Equatorial, using the Ring Micrometer with power 100.

Date. 1899.	G.M.T. h m s	Local Sidereal Time. h m s	Observer.	Comet *minus* Star. (Corrected for Refraction only). R.A. m s	N.P.D. ′ ″	No. of Compa.	Apparent R.A. of Comet. h m s	Parallax in R.A. *p*. s	Log. ($p \times \Delta$).	Apparent N.P.D. of Comet. ° ′ ″	Parallax in N.P.D. *q*. ″	Log. ($q \times \Delta$).	Ref.
June 12	12 42 32	18 1 57	R.	−2 23·25	+1 47·9	3	19 50 24·22	−0·31	−9·2211	94 46 (44·6)	13·5	0·8626	(*a*)
14	12 21 12	17 48 27	R.	−4 40·81	−0 12·4	5	19 53 13·34	−0·36	−9·2791	95 3 31 6	13·8	0·8628	(*b*)
16	12 16 56	17 52 3	R.	+0 6·91	−0 31·7	12	19 56 1·66	−0·37	−9·2761	95 22 51·3	14·2	0·8641	(*c*)

Observer's Remarks.

(*a*) Comet small and excessively faint. Observations on this night are only approximate; the resulting N.P.D. has, therefore, been bracketed.

(*b*) The comet has a small nebulous head, with a stellar condensation of about magnitude 12. The comparison star is of the 10th magnitude.

(*c*) The comet is small and faint, with a condensation of about the 12th magnitude. The magnitude of the comparison star is 11.

Adopted Places of the Comparison Stars.

Ref.	Mean R.A. 1899·0. h m s	Reduction to Appar. R.A. s	Mean N P.D. 1899·0. ° ′ ″	Reduction to Appar. N.P.D. ″	Authority.
(*a*)	19 52 43·88	+3·59	94 45 4·35	−7·65	Three observations Radcliffe Transit Circle, 1899.
(*b*)	19 57 50·54	+3·61	95 3 52·38	−8·40	Five observations R.A. and three observations N.P.D. Radcliffe Transit Circle, 1899.
(*c*)	19 55 51·07	+3·68	95 23 31·52	−8·61	Three observations Radcliffe Transit Circle, 1899.

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85, and the geocentric distances, Δ, are taken from the *Astronomische Nachrichten*, No. 3554.

Observer: Mr. W. H. Robinson.

Radcliffe Observatory, Oxford: 1902 *July* 9.

Old Cape Records of Comets. By R. T. A. Innes.

In arranging the old records of the Cape Observatory I came across a letter giving some records of comets seen from the Cape in the seventeenth century. With Sir David Gill's sanction I transmit a copy of it. The year of the letter is not given. It was probably written in 1858 to 1860, but the exact date is immaterial.

February 28.

My Dear Sir,—In my rapid progress through the old journals my eye has been caught by the notices of which I annex the translations. I may have passed over some others from the impossibility of attempting to do more than skim, but if there are any years in particular during which a more particular examination would [be] interesting to you, pray let me know the years, and I shall not fail to look more closely.—I am, &c., (Signed) D. Moolin.

T. Maclear, Esq.

1664 December 15.—"About midnight, with a sky partially clouded, we all here saw a star with a darkish ray or tail, which it is said showed itself much more clearly and distinctly about 3 o'clock when it was near day; the star rose in the East and the tail pointed directly North."

1686, Monday, August 12.—"This night appeared in the 5th house of the heavens, at one o'clock, in the horizon, *a comet*, corresponding in longitude (♑) with *Saturn* and *Venus*, on the left shoulder of the *Hare*. S. Lat. 18° 4′, Long. 80° 8′. The tail extended right East and West to the length of 35 Celestial Degrees, in *Gemini*."

1689 November 24.—"A star with a tail was seen in the [MS. defaced]."

1689 November 25.—"This morning about 4 o'clock the said tailed star was again seen, which soon after disappeared as the Sun rose."

1689 December 9.—"This morning at 3 o'clock the tailed star showed itself very distinctly, the tail was more than 4 degrees long."

1689 December 24.—"The tailed star no longer seen."

On the Place of a Star near the Variable RU Herculis. (Correction to former paper.) By F. A. Bellamy.

In a letter, Fr. Hagen has kindly drawn attention to a discrepancy between his observation and the position of star No. 19 as given in my paper (*Monthly Notices*, lxii. p. 75). Upon examination the cause was found to be in the transcription from the original measure sheets to the computation forms preliminary to conversion of measured coordinates to R.A. and Dec.: the line of figures opposite star No. 19 should read thus :—

19	11·0	8·3363	5·6320	$6^m\ 16^s{\cdot}76$	$23'\ 7''{\cdot}4$

The computations have been examined for the other stars but no further errors were found.

On Mr. Love's Formula for the Wave-Lengths of Nebular Lines. By W. H. Wright.

(*Communicated by the Secretaries.*)

In the May number of the *Monthly Notices* of the Royal Astronomical Society, Mr. E. F. J. Love publishes a note on a relation which he considers to exist among the wave-lengths of some of the nebular lines. The supposed law, expressed in the general form adopted by Runge and others in their work on line series in the spectra of some of the elements, is as follows :

$$\lambda^{-1} = 25739 + 43108\, n^{-2} - 1412208\, n^{-4} \quad \ldots \quad \ldots \quad (1)$$

Such a law would be of the greatest interest and importance, not only by virtue of the fact that it would bring another spectrum into the line-series class, but also on account of the light it would shed on the composition of the nebulæ by correlating a certain number of the "unknown" lines, and indicating their common origin. But, great as is the desideratum for such an expression of relation, the writer is inclined to doubt that any physical significance attaches to Mr. Love's formula. A number of reasons for this point of view will be given as briefly as possible.

In the following table the values of λ as determined from equation (1) are tabulated with n as argument :

TABLE I.

n	λ computed.	λ in nebulæ.	
3	7637·0	not observed.	
4	4363·6	4363·3	Used to deduce the formula.
5	3967·6	3967·6	
6	3868·9	3868·9	
7	41·6	not observed.	
8	36·1	3836* (Campbell).	
9	37·9	not observed.	
10	41·9	3842 (Huggins).	
11	46·3	not observed.	
12	50·6	not observed.	
13	54·4	3854 (Huggins).	

By assuming $n = 11{\cdot}5$ and $14{\cdot}5$, additional approximate coincidences are secured with two of the lines observed by Huggins.

Let us examine somewhat critically the identities assumed by Mr. Love, as given in column three of the above table. As he points out, it is hardly probable that a line at λ 7637 would be observed in a nebular spectrum, supposing it were present. The agreement of the next three wave-lengths should follow as a matter of necessity, as they were used in computing the constants of the formula. Owing, however, to some slight numerical error, there is a discrepancy of 0·3 tenth-metre between the observed and computed values of the line λ 4363. Just what effect the correction of this error would have on the computed wave-lengths I have not determined. It is probable that the change would not amount in any case to more than one unit.

Passing for a moment the identification of the value $n = 8$, we come to the lines observed by Huggins. With regard to them it may be said that they are only a few of a group reported by that observer as existing in this region of the spectrum. The entire group is as follows : $\lambda\lambda$ 3896, 3887, 3878, 3870, 3859, 3854, 3848, 3842, 3832 and 3825. Under the circumstances some apparent coincidences are to be expected. Attention should moreover be called to the fact that there appears to be a systematic difference between Huggins's determinations and my own (from which the constants of Mr. Love's formula were computed) amounting to about $+2{\cdot}5$ tenth-metres (W—H). This difference was determined from the three lines $\lambda\lambda$ 5007, 4959, and 3727, and is partly to be accounted for by the difference between the Angström and Rowland scales, amounting

* The wave-length published by Campbell is λ 3835. The wave-length given in the table is the one assumed by Mr. Love in his discussion.

in this region to about 0·8 tenth-metre. The reason for the choice of these particular lines is that they are the only lines measured by both Sir William Huggins and myself concerning which assumptions could not be made as to wave-length. The other lines measured by both observers were by each assumed to be due to hydrogen, and cannot therefore be used for the present purpose. Assuming that the difference +2·5 affects the group of lines under discussion, the coincidences in Table I. are destroyed. There is, however, a line in the group at λ 3848, and applying the correction we have a coincidence with the value 3850·6 corresponding to $n = 12$, a fact which indicates, perhaps, as much as anything else, the likelihood of occasional coincidences in a case of this sort. It should further be stated that the group of lines mentioned was observed only on the much discussed 1888 negative secured by Sir William and Lady Huggins. This photograph was taken fourteen years ago, and, although its indications were of remarkable interest, they have not since been confirmed, though attempts were made by several observers—notably Keeler, Campbell, and Huggins himself—to repeat the observations.

The only coincidence, then, to be taken seriously is that of λ 3836. This line has been identified by Campbell and others as $H\eta$ (λ 3835·6), and there is little reason to doubt that the identification is correct. It is one of a series of lines in the spectrum of the *Orion* nebula, the members of which decrease regularly in intensity towards the violet, and agree, within the limits of observational error, with the lines of the well-known hydrogen series. In Table II. are the wave-lengths as measured by Campbell in the nebular spectrum, and by Ames in the spectrum of hydrogen.

TABLE II.

Nebulæ.	Hydrogen tube.	Nebulæ.	Hydrogen tube.
4861	4861·5	3835	3835·6
4341	4340·6	3798	3798·0
4102	4101·9	3770	3770·7
3969	3970·2	3749	3750·2
3889	3889·2		

The wave-length λ 3969 in the nebular spectrum is of course that of the centre of gravity of the doublet λλ 3967·6 and 3970·2, which accounts for the apparent discrepancy shown by the table. λ 3749 is marked by Campbell as "very faint," and was therefore probably a difficult line to measure. In this case the residual is slightly over a tenth-metre, while in all the others the residuals are less than this amount. It is then difficult to interpret Mr. Love's statement, made in substantiation of his belief that "the hydrogen series beyond $H\varepsilon$ has probably not yet been detected in nebular spectra," to the effect that he

finds it "much easier to believe some of Campbell's identifications wrong than to believe that his measurements are incorrect by three and four tenth-metres." Campbell's measurements seem to the writer to constitute a proof that the ultra-violet hydrogen series has been observed in the *Orion* nebula as far as $H\kappa$, and that the line λ 3835 is due to hydrogen. But, however that may be, evidence is not lacking that the line does not belong to a series including $\lambda\lambda$ 4363, 3968, and 3869. The line in question does not appear to vary in intensity in a regular manner with the latter lines, unless indeed the relation be an inverse one. The line λ 3835 and those in Table II. to the violet of it have been observed only in the *Orion* nebula, an object in which the hydrogen lines are unusually bright, and the three lines mentioned comparatively faint. It is in the planetary nebulæ, in which the line λ 3835 is too faint for observation, that the three lines taken by Mr. Love as the basis of his series are bright.

In view of the above facts the writer considers that there is not a single coincidence between computed and observed wavelengths upon which the proposed formula can be considered to rest.

The writer considers it very doubtful whether λ 4363 is emitted under the same conditions as $\lambda\lambda$ 3968 and 3869. The latter lines are of about the same intensity in a number of different nebulæ,* but the intensity of λ 4363 appears to vary relatively to them more than can be accounted for by instrumental considerations. So far as the three corresponding *Nova* bands being characterised by an identity of structure is concerned, the observations made at the Lick Observatory show the structure of all the brighter lines to be pretty much the same.

Lick Observatory: 1902 *August.*

Explanation of Use of Tables of $\frac{1}{2}(\theta+\cos\theta)$.

By W. Steadman Aldis, M.A.

The equations connecting the eccentric, true, and mean anomalies, and radius vector in an elliptic orbit are

$$(1) \qquad m = u - e\sin u\,;$$

$$(2) \qquad \tan\frac{v}{2} = \sqrt{\frac{1+e}{1-e}}\tan\frac{u}{2}\,;$$

$$(3) \qquad r = a(1-e\cos u).$$

* Lick Observatory Bulletin, No. 19.

Putting $e = \sin\phi$, (1) becomes

$$\begin{aligned} m &= u - \sin\phi \sin u \\ &= \tfrac{1}{2}\{\phi + u + \cos(\phi+u)\} - \tfrac{1}{2}\{\phi - u + \cos(\phi-u)\} \\ &= C(\phi+u) - C(\phi-u) \end{aligned}$$

if $C(\theta)$ denote $\frac{1}{2}(\theta + \cos\theta)$.

The accompanying tables give the value of $C(\theta)$ in seconds for every minute of angle between $-90°$ and $+90°$.

For values beyond these limits it is easily shown that

$$\begin{aligned} C(180°-\theta) &= N - C(\theta) \\ C(-180°+\theta) &= -N - C(-\theta) \\ C(180°+\theta) &= N - C(-\theta) \end{aligned}$$

where $N = 324000$ = number of seconds in a right angle.

Examples of Use.

The Observatory, 1895 March, gave elements of Barnard's Comet.

Epoch 1895, Feb. 9·0, Berlin Mean Time.

$M = 339°\ 8'$, $\phi = 35°\ 43'$, $\mu = 656''$, $\log a = 0{\cdot}4886$.

These give the values of the mean anomaly at midnight on the dates named according to the subjoined table :

Date.	Mean Anomaly.	Date.	Mean Anomaly.
	"		"
May 26	−5584	May 31	−2304
27	−4928	June 1	−1648
28	−4272	2	− 992
29	−3616	3	− 336
30	−2960	4	+ 320

The negative sign merely indicates the anomaly as measured on the preceding side of the apse line.

To find the eccentric anomaly corresponding to mean anomaly 320″ at June 4 midnight we have

$$320 = C(\phi+u) - C(\phi-u) \quad \ldots \quad \ldots \quad (a)$$

where $\phi = 35°\ 43'$

The tables show that a change of 1′ up or down in θ from $35°\ 43'$ gives a change of about 12″·48 in $C(\theta)$.

Hence the value of u to satisfy (a) will be about $\frac{320}{2 \times 12{\cdot}48}$ minutes; that is to say, u lies between 12′ and 13′.

Take $u = 12'$; from the tables.

$C(\phi+u) = C(35^\circ\ 55') = 148173''\cdot9463$ diff. for $1'$ in $u = 12''\cdot3982$

$C(\phi-u) = C(35^\circ\ 31') = 147874''\cdot2652$ " " in u downwards $= 12''\cdot5754$

difference $= 299''\cdot6811$

This is too small by $20''\cdot3189$, and as an increase of $1'$ in u would increase this on the whole by $24\cdot9736$, the required increase must be $\frac{20\cdot3189}{24\cdot9736} \times 60'' = 48''\cdot8$.

Thus $u = 12'\ 48''\cdot8$.

Take midnight, May 26; neglecting the sign,

$$m = 5584'' = C(\phi+u) - C(\phi-u).$$

A first approximation, by difference opposite $35^\circ\ 43'$, gives

$$u = \frac{5584}{2 \times 12\cdot48} \text{ minutes} = 3^\circ\ 42' \text{ about.}$$

With this value

$C(\phi+u) = C(39^\circ\ 25') = 150624''\cdot8251$, diff. for $60'' = 10''\cdot9480$

$C(\phi-u) = C(32^\circ\ 1') = 145075''\cdot3368$ " " downwards $= 14''\cdot0987$

difference $= 5549''\cdot4883$

This is too small by $34''\cdot5117$, and u therefore must be increased by $\frac{34\cdot5117}{25\cdot0467} \times 60'' = 1'\ 22''\cdot7$.

Thus $u = 3^\circ\ 43'\ 22''\cdot7$.

When u is found (2) will give v. Equation (3) can be modified thus:

$$r = a(1-e\cos u)$$

or

$$r = a(1-\sin\phi\cos u)$$

$$= a\left\{\frac{1-\sin(\phi+u)}{2} + \frac{1-\sin(\phi-u)}{2}\right\}$$

$$= a\left\{\left(\frac{dC}{d\theta}\right)_{\theta=\phi+u} + \left(\frac{dC}{d\theta}\right)_{\theta=\phi-u}\right\}$$

Now the difference between two consecutive values of $C(\theta)$ in the tables, divided by 60, is clearly a very close approximation to the value of $\left(\frac{dC}{d\theta}\right)$ for a value of θ halfway between the two consecutive arguments.

In the last example $\phi = 35^\circ\ 43'$,

$u = 3^\circ\ 43'\ 22''\cdot7$

$\phi+u = 39^\circ\ 26'\ 22''\cdot7$, $\phi-u = 31^\circ\ 59'\ 37''\cdot3$

From the tables $\left(\frac{dC}{d\theta}\right)_{\theta=39^\circ\ 26'\ 30''} = \frac{10\cdot9412}{60} = \cdot18235$

while the value for 39° 25′ 30″ is ·18247. Thus the value of

$$\frac{dC}{d\theta} \text{ for } \theta = 39°\ 26'\ 22''{\cdot}7 \text{ is } {\cdot}18236 \text{ very nearly.}$$

Similarly for

$$\theta = 31°\ 59'\ 37''{\cdot}3, \quad \frac{dC}{d\theta} = {\cdot}23509$$

Thus $r = a \times {\cdot}20878$

which is accurate within the limits of the data.

Taking as an example an orbit of large eccentricity and also taking a large mean anomaly, that of Halley's Comet, Epoch 1910 (from *Encyclopædia Britannica*)

$a = 17{\cdot}9555$, Period 76·085 yrs., $e = {\cdot}961733$, T = May 26·83.

Hence on May 26·83, 1900, the mean anomaly of the comet was

$$\frac{10 \times 360 \times 60 \times 60}{76{\cdot}085} \text{ seconds} = 170335''{\cdot}8 \text{ nearly}$$

$$= 31°\ 48'\ 55''{\cdot}8 \text{ nearly}$$

Since $m = u - e \sin u$

$u = m + e \sin m$. 1st approximation ... (A)

$= m + (e + e^2 \cos m) \sin m$

$= m + e' \sin m$. 2nd approximation ... (B)

With the 1st approximation

$$u = C(m-\phi) - C(-m-\phi)$$

But $m =$	31°	48′	55″·8
ϕ	74	5	53·8
$m-\phi =$	−42	16	58
$m+\phi$		105	55

$= -42°\ 17'$ approximately

"

Now $C(-105°\ 55') = -N - C(-74°\ 5')$.

Hence the first approximation to the value of u is given by

$$C(m-\phi) = 190''{\cdot}1194$$

$$N = 324000{\cdot}$$

$$324190{\cdot}1194$$

$$C(-74°\ 5') = -105067{\cdot}0764$$

and $$u = 219123{\cdot}0430$$

$$= 60°\ 52'\ 3'' \text{ nearly.}$$

Take as a trial value $u = 60^\circ\ 52'$

$$\phi = 74\ \ 6$$

$$C(\phi+u) = C(180^\circ-45^\circ\ 2') = N-C(45^\circ\ 2')$$
$$C(\phi-u) = C(13^\circ\ 14')$$

$C(45^\circ\ 2') = 153943''\cdot1829$ diff. for $60'' = 8''\cdot7713$
$C(13\ 14) = 124213\cdot8138$ „ „ $23\cdot1283$
sum $= 278156\cdot9967$
$324000\cdot$
$m = 45843\cdot0033$

The deficiency in the value of m is $134492''\cdot8$. The increase in the value of m for a change of $1'$ in u is at the present point about $8''\cdot8+23''$, or roughly $32''$. If this continued uniform, an addition of $\frac{134492\cdot8}{32}$ minutes would have to be made to u, or of $70^\circ\ 31'$.

This would make

$$u = 130^\circ\ 55',\quad \phi+u = 205^\circ\ 1' = 180^\circ+25^\circ\cdot1$$
$$\phi-u = -56^\circ\ 49'$$

and at this point a change of $1'$ in u would make a total change of $42''\cdot7+55''\cdot1$, or nearly $98''$, in m; nearly three times the amount at starting. If we assume an average change of double the original value of the increment, the required change in u will be 35°. This gives $u = 95^\circ\ 52'$

$$\therefore\ (\phi+u) = 169^\circ\ 58' = 180-10^\circ\ 2'$$
$$(\phi-u) = -21^\circ\ 46'.$$

Hence $m = N-C(10^\circ\ 2')-C(-21^\circ\ 46')$.

Now

$C(10^\circ\ 2') = 119615''\cdot1541$, diff. for $1' = 24''\cdot7691$
$C(-21\ 46) = 56599\cdot2405$ „ „ $41\cdot1289$
$176214\cdot3946$
$324000\cdot$

Thus $m = 147785\cdot6054$

The deficiency is now $22550''$, and the change in m for an increase of $60''$ in u is about $66''$. This change increases as u increases, and if it be assumed on an average to be about $70''$, an increment to u of about 5° is needed.

Thus $u = 100° 52'$

and $m = N - C(5° 2') - C(-26° 46')$

$C(5° 2') = 111794''.7$, diff. for $1' = 27''.4$

$C(-26\ 46) = 43901.6$ " " " 43.5

155696.3

324000

$m = 168303.7$

deficiency now $= 2032''.1$, and as the change in m for a change of $60''$ in u is about $71''$, this requires an addition to u of about $\frac{2032.1'}{71}$, or between $28'$ and $29'$.

Taking $28'$, $u = 101° 20'$, and repeating the process, if it is desired to be very accurate, taking $\phi = 74° 5' 53''.8$ instead of $74° 6'$ it will turn out that the correct value is $101° 20' 33''.2$, the error being less than a tenth of second.

The first guess can be often made more correct by taking (B) instead of (A), and finding an angle ϕ' such that

$$\sin \phi' = e + e^2 \cos m, \text{ whence (B) gives}$$
$$u = C(m - \phi') - C(-m - \phi')$$

as a first approximation. Or if $e + e^2 \cos m$ is greater than unity, writing $90°$ for ϕ'

$$u = C(m - 90°) - C(-m - 90°).$$

When u is known, r can be found from the column of differences, as in the former example.

Part 2.

A second use to which the tables can be applied is that of finding the elements of an elliptic orbit when two focal distances, the angle between them, and the time occupied in passing from one position to the other are known.

If (r, θ), (r', θ') be the focal polar coordinates of the two positions, and t the time occupied in passing between them, it is known that the following equation holds:

$$\frac{kt}{a^{\frac{3}{2}}} = (\epsilon - \sin \epsilon) - (\delta - \sin \delta) \quad \ldots \quad \ldots \quad (1)$$

where $$\cos \delta = 1 - \frac{r + r' - c}{2a} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

$$\cos \epsilon = 1 - \frac{r + r' + c}{2a} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

c being the length of the chord joining the two points and k the measure of the attractive force at unit distance.

Equation (1) can be written

$$\frac{kt}{a^{\frac{3}{2}}} = \left\{\frac{\pi}{2} - \delta + \cos\left(\frac{\pi}{2} - \delta\right)\right\} - \left\{\frac{\pi}{2} - \varepsilon + \cos\left(\frac{\pi}{2} - \varepsilon\right)\right\}$$

or
$$\frac{\frac{1}{2}kt}{a^{\frac{3}{2}}} = C(90-\delta) - C(90-\varepsilon) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

if k be expressed in seconds and δ and ε in degrees and parts of a degree.

The angle δ lies between 0° and 180°, or between 180° and 360°, according as $\theta \sim \theta'$ is less or greater than 180°, while ε is only restricted to lie between 0° and 360° (Gauss, *Theoria Motus*, ed. 2, Gotha, 1877, p. 132).

The three equations (1), (2), (3) are sufficient to determine δ, ε, and a. The last two can be written

$$\sin^2\tfrac{1}{2}\delta = \frac{r+r'-c}{4a} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

$$\sin^2\tfrac{1}{2}\varepsilon = \frac{r+r'+c}{4a} \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

whence
$$\sin\tfrac{1}{2}\delta = \sqrt{\frac{r+r'-c}{r+r'+c}} \cdot \sin\tfrac{1}{2}\varepsilon \quad \ldots \quad \ldots \quad (7)$$

The following process of successive approximation will give the value of a to as great a degree of accuracy as the data allow.

Assume any value for ε. From (7) the corresponding value of δ can be deduced, or, as is more useful in practice, a can be first derived from (6) and then δ from (5).

Placing the values of δ and ε in (4), by means of the tables of $C(\theta)$ another value of a is obtained. Let the values of a given by (6) and (4) be called x and y respectively.

Repeat this process with another assumed value of ε, and let x' and y' be the corresponding quantities on the second assumption. A comparison of $x' \sim y'$ with $x \sim y$ will indicate which of the two assumed values of ε is nearer the truth, and, with practice, will also give to a considerable degree of correctness the distance of the required value from the original assumption.

Taking an example worked out by Gauss (*Theoria Motus*, p. 103), we have

$$\log r = 0{\cdot}3307640$$
$$\log r' = 0{\cdot}3222239$$
$$\theta' - \theta = 7^\circ\ 34'\ 53''{\cdot}73$$
$$t = 21{\cdot}93391 \text{ days}$$

Also
$$\log k = 3{\cdot}5500065746$$
$$\log t = 1{\cdot}3411160571$$

whence
$$\log(\tfrac{1}{2}kt) = 4{\cdot}5900926360$$

Ordinary trigonometrical processes give

$$c = 0{\cdot}2835079$$

while $$r+r' = 4{\cdot}2417487$$

whence $$r+r'+c = 4{\cdot}5252566$$

$$r+r'-c = 3{\cdot}9582408$$

And $$\log\frac{r+r'+c}{4} = 0{\cdot}0535832$$

$$\log\frac{r+r'-c}{4} = 9{\cdot}9954422$$

For a first guess it is convenient to take $90°-\epsilon = 0$.

Thus $$\mathrm{L}\sin\tfrac{1}{2}\epsilon = 9{\cdot}8494850$$

$$\log\sin^2\tfrac{1}{2}\epsilon = 9{\cdot}6989700$$

$$\log\frac{r+r'+c}{4} = 0{\cdot}0535832$$

Hence $$\log x = 0{\cdot}3546132$$

$$\log\frac{r+r'-c}{4} = 9{\cdot}9954422$$

By (5) $$\log\sin^2\tfrac{1}{2}\delta = 9{\cdot}6408290$$

$$\mathrm{L}\sin\tfrac{1}{2}\delta = 9{\cdot}8204145$$

Whence $\frac{1}{2}\delta = 41° 24' 3''{\cdot}4$ and $\delta = 82° 48' 6''{\cdot}8$

$$(90-\delta) = 7° 11' 53''{\cdot}2$$

From the tables $\mathrm{C}(7° 11') = 115252''{\cdot}9290$

diff. for $60'' = 26''{\cdot}2443$

Whence, neglecting second differences at this stage,

$$\mathrm{C}(7° 11' 53''{\cdot}2) = 115276''{\cdot}1989$$

Also $$\mathrm{C}(90-\epsilon) = 103132''{\cdot}4031$$

$$\text{difference} = 12143''{\cdot}7958$$

The logarithm of this $$= 4{\cdot}0843545$$

$$\log\tfrac{1}{2}(kt) = 4{\cdot}5900926$$

$$\log a^{\frac{1}{2}} = \text{the difference} = 0{\cdot}5057381$$

$$2$$

$$3)1{\cdot}0114762$$

$$\log y = 0{\cdot}3371587$$

The values of x and y are nearer than they usually come at the first guess. Experience, or the theory of the equations (6) and (4), shows that if ϵ be diminished both x and y increase, but y increases faster than x; and if ϵ be increased x and y decrease,

the rate of change of y being the greater. As here y is less than x, it follows that in order to produce the required equality between them both must be increased, and ϵ and δ consequently diminished.

As a second guess take $\epsilon = 80°$. By the same process as above $\delta = 73° 54' 26''\cdot73$.

$$\log x = 0\cdot4374482$$
$$\log y = 0\cdot4407142$$

Thus y is now greater than x, and the second value of ϵ is too small.

Roughly, the values of x and y for $\epsilon = 90°$ and $\epsilon = 80°$ are $x_1 = 2\cdot2626$, $y_1 = 2\cdot1735$, $x_2 = 2\cdot7381$, $y_2 = 2\cdot7588$. Thus

$$x_1 - y_1 = \cdot0891,\ y_2 - x_2 = \cdot0207$$

and, assuming that $x \sim y$ changes uniformly with ϵ, this would give as the correct value of ϵ about $81° 53' 7''$.

In the later stages of approximation it is generally best to take two trial values of ϵ between which the real value lies, the simultaneous working of which is not much more labour than that of one separately, as far as reference to tables is concerned. A little practice will show what can easily be proved, that the rate of change of $y \sim x$ increases as δ decreases, and *vice versa*. Hence the real value of ϵ in this case is less than $81° 53' 7''$. Taking as two trial values for ϵ, $81° 54'$ and $81° 30'$, the corresponding values of δ are $75° 36' 30''\cdot6$ and $75° 15' 2''\cdot74$, while the values of $\log x$ and $\log y$ are given by

$$\left.\begin{aligned}\log x_1 &= 0\cdot4205700\\ \log y_1 &= 0\cdot4201511\end{aligned}\right\} \text{ and } \begin{aligned}\log x_2 &= 0\cdot4240764\\ \log y_2 &= 0\cdot4244420\end{aligned}$$

The required value of ϵ must evidently therefore lie between $81° 30'$ and $81° 54'$, and not very far from halfway between them. As another pair of trial values taking $\epsilon = 81° 40'$ and $\epsilon = 81° 42'$, by the same process it will be found that

$$\left.\begin{aligned}\log x_1 &= 0\cdot4226124\\ \log y_1 &= 0\cdot4226428\end{aligned}\right\} \qquad \begin{aligned}\log x_2 &= 0\cdot4223202\\ \log y_2 &= 0\cdot4222933\end{aligned}$$

The real value of ϵ is thus intermediate between these two.

The value of a must therefore lie between x_1 and x_2: that is, between 2·6461 and 2·6443. In many cases this will be near enough, but if greater accuracy is required a pair of closer values may be tried, from which it will be found that for $\epsilon = 81° 41' 11''\cdot5$, the values of $\log x$ and $\log y$ coincide for seven figures, each of them being 0·4224385. The value given by Gauss is 0·4224389, the discrepancy being within the limits of error accumulating in the use of seven-figure logarithms.

The discovery of the value of a, by means of the equations

(4), (6), and (7), may be considered as the discovery of the point of intersection of two curves whose equations are of the forms

$$y = \frac{\lambda}{\sin^2 \frac{1}{2}x} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

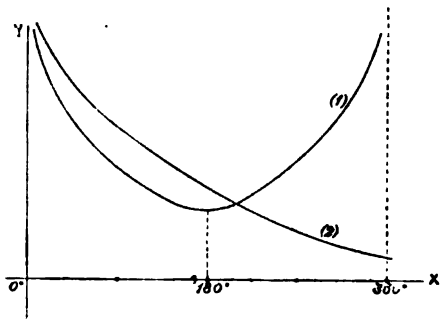
$$\frac{\mu}{y^{\frac{3}{2}}} = (x' - \sin x') - (x - \sin x) \quad \ldots \quad \ldots \quad (2)$$

where x' is a function of x given by an equation of the form

$$\sin \tfrac{1}{2}x' = \nu \sin \tfrac{1}{2}x,$$

λ, μ, ν being given constants.

The ordinate of the point of intersection is the required value of a.



The general form of these curves is as represented in the diagram. The axis of y is asymptotic to both, but, while the ordinate of (1) decreases until $x = 180°$, and then increases till it becomes infinite again when $x = 360°$, the ordinate of (2) continually decreases as x passes from 0° to 360°. It is not difficult to prove that in all cases of elliptic orbits the ordinate of (2) is greater than that of (1) for very small values of x. Obviously the two curves will cut each other in one point, and one point only, between the permissible limits of the value of x.

If then the values of the ordinate for each of the curves be calculated for two assumed values of x, as in the example worked out, and the points be marked down on a piece of scale paper, curves of the required general shape can be roughly drawn through the pairs of points thus found, and the point of their intersection will give an approximate starting point for the closer calculation of the correct value.

When in any example the value of a has been thus obtained, the values of the eccentricity and semilatus rectum can be found.

The formulæ for this purpose are easily shown to be

$$p = \frac{2rr'\sin^2\Delta}{c}\tan\tfrac{1}{2}\psi \text{ or } \frac{2rr'\sin^2\Delta}{c}\cot\tfrac{1}{2}\psi$$

where p is the semilatus rectum, 2Δ the angle between the given radii vectores, and ψ an acute angle determined by the equation

$$\left(r+r'-\frac{rr'\cos^2\Delta}{a}\right)\sin\psi = c.$$

In the formula for p the value $\tan\frac{1}{2}\psi$ or $\cot\frac{1}{2}\psi$ has to be taken according as 2Δ, or $\theta'-\theta$ is greater or less than 180°. When p is known and a, the value of e can be obtained from the formula $p = a(1-e^2)$, or if $e = \sin\varphi$, $\cos\phi = \sqrt{\frac{p}{a}}$.

In using this method for finding a it is better to make an assumption for the value of ϵ than for that of δ although the range of possible values for the former is double that for the latter, for two reasons. First, for any assumed value of ϵ, equation (7) only gives one value of δ, while for an assumed value of δ it would give two possible ones for ϵ; secondly, any assumed value for ϵ will give a real value for δ, while this would not always be the case if the opposite method were adopted.

In the tables negative values of $C(\sigma)$ are denoted by a black line at the right of the column.

In cases where there was a little doubt as to whether the figure after the fourth decimal ought to be 5+ or 5−, so that there was uncertainty as to the exact value of the last figure retained, that value has been chosen which made the sequence of the second differences most regular.

A dot placed after a decimal whose last significant figure is 5, thus ·6345. or ·6350. denotes that the real value is slightly less. This enables the last digit or two digits to be cut off with accuracy in all cases.

The writer desires to acknowledge his obligation to Professor G. H. Darwin for valuable hints as to the construction and the method of application of the Tables.

Δ².	Diff.	0°.	,	−0°.	Diff.	Δ².	Δ².	Diff.	1°.
	"	"		"	"			"	"
86		103132·4031	0	103132·4031		86	87		104916·6956
88	29·9957	162·3988	1	102·3988	30·0043	88	88	29·4721	946·1677
87	·9869	192·3857	2	072·3857	·0131	87	87	·4633	104975·6310
88	·9782	222·3639	3	042·3639	·0218	88	87	·4546	105005·0856
87	·9694	252·3333	4	103012·3333	·0306	87	88	·4459	034·5315
87	·9607	282·2940	5	102982·2940	·0393	87	86	·4371	063·9668
87	·9520	312·2460	6	952·2460	·0480	87	88	·4285	093·3971
87	·9433	342·1893	7	922·1893	·0567	87	87	·4197	122·8168
88	·9346	372·1239	8	892·1239	·0654	88	88	·4110	152·2278
87	·9258	402·0497	9	862·0497	·0742	87	86	·4022	181·7300
	·9171				·0829			·3936	
87		431·9668	10	831·9668			88		211·2236
88	·9084	461·8752	1	801·8752	·0916	87	87	·3848	240·7084
87	·8996	491·7748	2	771·7748	·1004	88	88	·3761	269·7845
87	·8909	521·6657	3	741·6657	·1091	87	86	·3673	299·1513
87	·8822	551·5479	4	711·5479	·1178	87	88	·3587	328·5105
88	·8735	581·4214	15	681·4214	·1265	88	87	·3499	357·8604
87	·8647	611·2861	6	651·2861	·1353	87	88	·3412	387·2012
87	·8560	641·1421	7	621·1421	·1440	87	86	·3324	416·5345
87	·8473	670·9894	8	590·9894	·1527	87	88	·3238	445·8578
88	·8386	700·8280	9	560·8280	·1614	88	87	·3150	475·1728
	·8298				·1702			·3063	
87		730·6578	20	530·6578		87	87		504·4781
87	·8211	760·4789	1	500·4789	·1789	87	88	·2976	533·7757
87	·8124	790·2913	2	470·2913	·1876	87	87	·2888	563·0653
88	·8037	820·0950.	3	440·0950.	·1963	88	87	·2801	592·3456
87	·7949	849·8899	4	409·8899	·2051	87	87	·2714	621·6170
87	·7862	879·6761	25	379·6761	·2138	87	87	·2627	650·8787
88	·7775	909·4536	6	349·4536	·2225	88	88	·2540	680·1337
87	·7687	939·2223	7	319·2223	·2313	87	87	·2452	709·3786
87	·7600	968·9823	8	288·9823	·2400	87	88	·2365	738·6151
87	·7513	103998·7336	9	258·7336	·2487	87	86	·2277	767·8431
	·7426				·2574			·2191	
88		104028·4762	30	228·4762		88	88		797·0622
87	·7338	058·2100	1	198·2100	·2662	87	87	·2103	826·2725
87	·7251	087·9351	2	167·9351	·2749	87	87	·2016	855·4741
88	·7164	117·6515.	3	137·6515.	·2836	88	87	·1929	884·6670
86	·7076	147·3591	4	107·3591	·2924	86	88	·1842	913·8512
88	·6990	177·0581	35	077·0581	·3010	88	87	·1754	943·0266
87	·6902	206·7483	6	046·7483	·3098	87	87	·1667	105972·1933
87	·6815	236·4298	7	102016·4298	·3185	87	87	·1580	106001·3513
88	·6728	266·1026	8	101986·1026	·3272	88	88	·1493	030·5006
87	·6640	295·7666	9	955·7666	·3360	87	86	·1405	059·6411
	·6553				·3447			·1319	
87		325·4219	40	925·4219		87	88		088·7730
88	·6466	355·0685.	1	895·0685.	·3534	88	88	·1231	117·8961
87	·6378	384·7063	2	864·7063	·3622	87	86	·1143	147·0104
87	·6291	414·3354	3	834·3354	·3709	87	88	·1057	176·1161
87	·6204	443·9558	4	803·9558	·3796	87	87	·0969	205·2130
87	·6117	473·5675	45	773·5675	·3883	87	87	·0882	234·3012
88	·6030	503·1705.	6	743·1705.	·3970	88	87	·0795	263·3807
87	·5942	532·7647	7	712·7647	·4058	87	88	·0708	292·4515
87	·5855	562·3502	8	682·3502	·4145	87	87	·0620	321·5135
88	·5768	591·9270	9	651·9270	·4232	88	87	·0533	350·5668
	·5680				·4320			·0446	
87		621·4950	50	621·4950		87	87		379·6114
87	·5593	651·0543	1	591·0543	·4407	87	88	·0359	408·6473
87	·5506	680·6049	2	560·6049	·4494	87	87	·0271	437·6744
88	·5419	710·1468	3	530·1468	·4581	88	87	·0184	466·6928
87	·5331	739·6799	4	499·6799	·4669	87	87	·0097	495·7025
87	·5244	769·2043	55	469·2043	·4756	87	87	29·0010	524·7035
87	·5157	798·7200	6	438·7200	·4843	87	87	28·9923	553·6958
88	·5070	828·2270	7	408·2270	·4930	88	88	·9836	582·6794
86	·4982	857·7252	8	377·7252	·5018	86	87	·9748	611·6542
88	·4896	887·2148	9	347·2148	·5104	88	88	·9661	640·6203
	29·4808	104916·6956	60	101316·6956	30·5192			28·9573	106669·5776

′	−1°.	Diff.	Δ².	Δ².	Diff.	2°.	′	−2°.	Diff.	Δ².
	″	″			″	″		″	″	
0	101316·6956		87	86		106669·5776	0	99469·5776		86
		30·5279			28·9487				31·0513	
1	286·1677		88	88		698·5263	1	438·5263		88
		·5367			·9399				·0601	
2	255·6310		87	87		727·4662	2	407·4662		87
		·5454			·9312				·0688	
3	225·0856		87	87		756·3974	3	376·3974		87
		·5541			·9225				·0775	
4	194·5315.		88	87		785·3199	4	345·3199		87
		·5629			·9138				·0862	
5	163·9686		86	88		814·2337	5	314·2337		88
		·5715			·9050				·0950	
6	133·3971		88	86		843·1387	6	283·1387		86
		·5803			·8964				·1036	
7	102·8168		87	88		872·0351	7	252·0351		88
		·5890			·8876				·1124	
8	072·2278		88	87		900·9227	8	220·9227		87
		·5978			·8789				·1211	
9	041·6300		86	88		929·8016	9	189·8016		88
		·6064			·8701				·1299	
10	101011·0236		88	86		958·6717	10	158·6717		86
		·6152			·8615				·1385	
1	100980·4084		87	88		106987·5332	1	127·5332		88
		·6239			·8527				·1473	
2	949·7845.		88	87		107016·3859	2	096·3859		87
		·6327			·8440				·1560	
3	919·1518		86	87		045·2299	3	065·2299		87
		·6413			·8353				·1647	
4	888·5105.		88	87		074·0652	4	034·0652		87
		·6501			·8266				·1734	
15	857·8604		87	88		102·8918	15	99002·8918		88
		·6588			·8178				·1822	
6	827·2016		88	87		131·7096	6	98971·7096		87
		·6676			·8091				·1909	
7	796·5340		86	87		160·5187	7	940·5187		87
		·6762			·8004				·1996	
8	765·8578		88	87		189·3191	8	909·3191		87
		·6850			·7917				·2083	
9	735·1728		87	87		218·1108	9	878·1108		87
		·6937			·7830				·2170	
20	704·4791		87	88		246·8938	20	846·8938		88
		·7024			·7742				·2258	
1	673·7767		88	86		275·6680	1	815·6680		86
		·7112			·7656				·2344	
2	643·0655		87	88		304·4336	2	784·4336		88
		·7199			·7568				·2432	
3	612·3456		87	87		333·1904	3	753·1904		87
		·7286			·7481				·2519	
4	581·6170		87	88		361·9385.	4	721·9385.		88
		·7373			·7393				·2607	
25	550·8797		87	86		390·6778	25	690·6778		86
		·7460			·7307				·2693	
6	520·1337		88	88		419·4085.	6	659·4085.		88
		·7548			·7219				·2781	
7	489·3789		87	87		448·1304	7	628·1304		87
		·7635			·7132				·2868	
8	458·6154		88	87		476·8436	8	596·8436		87
		·7723			·7045				·2955	
9	427·8431		86	87		505·5481	9	565·5481		87
		·7809			·6958				·3042	
30	397·0622		88	87		534·2439	30	534·2439		87
		·7897			·6871				·3129	
1	366·2725		87	88		562·9310	1	502·9310		88
		·7984			·6783				·3217	
2	335·4741		87	87		591·6093	2	471·6093		87
		·8071			·6696				·3304	
3	304·6670		87	87		620·2789	3	440·2789		87
		·8158			·6609				·3391	
4	273·8512		88	87		648·9398	4	408·9398		87
		·8246			·6522				·3478	
35	243·0266		87	87		677·5920	35	377·5920		87
		·8333			·6435				·3565	
6	212·1933		87	87		706·2355.	6	346·2355.		87
		·8420			·6348				·3652	
7	181·3513		87	88		734·8703	7	314·8703		88
		·8507			·6260				·3740	
8	150·5006		88	87		763·4963	8	283·4963		87
		·8595			·6173				·3827	
9	119·6411		86	87		792·1136	9	252·1136		87
		·8681			·6086				·3914	
40	088·7730		88	87		820·7222	40	220·7222		87
		·8769			·5999				·4001	
1	057·8961		88	87		849·3221	1	189·3221		87
		·8857			·5912				·4088	
2	100027·0104		86	88		877·9133	2	157·9133		88
		·8943			·5824				·4176	
3	99996·1161		88	87		906·4957	3	126·4957		87
		·9031			·5737				·4263	
4	965·2130		87	87		935·0694	4	095·0694		87
		·9118			·5650				·4350	
45	934·3012		87	87		963·6344	45	063·6344		87
		·9205			·5563				·4437	
6	903·3807		87	87		107992·1907	6	032·1907		87
		·9292			·5476				·4524	
7	872·4515.		88	87		108020·7383	7	98000·7383		87
		·9380			·5389				·4611	
8	841·5135.		87	88		049·2772	8	97969·2772		88
		·9467			·5301				·4699	
9	810·5668		87	87		077·8073	9	937·8073		87
		·9554			·5214				·4786	
50	779·6114		87	86		106·3287	50	906·3287		86
		·9641			·5128				·4872	
1	748·6473		88	88		134·8415.	1	874·8415.		88
		·9729			·5040				·4960	
2	717·6744		87	87		163·3455	2	843·3455		87
		·9816			·4953				·5047	
3	686·6928		87	88		191·8408	3	811·8408		88
		·9903			·4865				·5135	
4	655·7025		87	86		220·3273	4	780·3273		86
		30·9990			·4779				·5221	
55	624·7035		87	88		248·8052	55	748·8052		88
		31·0077			·4691				·5309	
6	593·6958		87	87		277·2743	6	717·2743		87
		·0164			·4604				·5396	
7	562·6794		88	87		305·7347	7	685·7347		87
		·0252			·4517				·5483	
8	531·6542		87	86		334·1864	8	654·1864		86
		·0339			·4431				·5569	
9	500·6203		88	88		362·6295.	9	622·6295.		88
		31·0427			28·4343				31·5657	
60	99469·5776					108391·0638	60	97591·0638		

Δ².	Diff.	3°.	′	−3°.	Diff.	Δ².	Δ².	Diff.	4°.
	″	″		″	″				
88	28·4255	108391·0638	0	97591·0638	31·5745	88	86	27·9030	110081·1777
87	·4168	419·4893	1	559·4893	·5832	87	87	·8943	109·0807
86	·4082	447·9061	2	527·9001	·5918	86	88	·8855	136·9750
88	·3994	476·3143	3	496·3143	·6006	88	87	·8768	164·8605
87	·3907	504·7137	4	464·7137	·6093	87	86	·8682	192·7373
87	·3820	533·1044	5	433·1044	·6180	87	88	·8594	220·6055
87	·3733	561·4864	6	401·4864	·6267	88	86	·8508	248·4646
88	·3645	589·8597	7	369·8597	·6355	86	88	·8420	276·3157
86	·3559	618·2242	8	338·2242	·6441	88	87	·8333	304·1577
88	·3471	646·5801	9	306·5801	·6529		87	·8246	331·9910
86		674·9272	10	274·9272	·6615	86	87	·8159	359·8156
88	·3385	703·2657	1	243·2657	·6703	88	87	·8072	387·6315
87	·3297	731·5954	2	211·5954	·6790	87	87	·7985	415·4387
88	·3210	759·9164	3	179·9164	·6878	88	87	·7898	443·2372
86	·3122	788·2286	4	148·2286	·6964	86	87	·7811	471·0270
87	·3036	816·5322	15	116·5322	·7051	87	87	·7724	498·8081
88	·2949	844·8271	6	084·8271	·7139	88	87	·7637	526·5805
86	·2861	873·1132	7	053·1132	·7225	86	87	·7550	554·3442
88	·2775	901·3907	8	97021·3907	·7313	88	88	·7462	582·0992
87	·2687	929·6594	9	96989·6594	·7400	88	86	·7376	609·8454
87	·2600	957·9194	20	957·9194	·7487	87	87	·7289	637·5830
87	·2513	108986·1707	1	926·1707	·7574	87	87	·7202	665·3119
88	·2426	109014·4133	2	894·4133	·7661	87	88	·7115	693·0321
87	·2339	042·6472	3	862·6472	·7749	88	86	·7027	720·7436
86	·2251	070·8723	4	830·8723	·7835	86	87	·6941	748·4463
88	·2165	099·0888	25	799·0888	·7923	88	87	·6854	776·1404
86	·2077	127·2965	6	767·2965	·8009	87	87	·6767	803·8258
88	·1991	155·4956	7	735·4956	·8097	86	87	·6680	831·5025
87	·1903	183·6859	8	703·6859	·8184	88	87	·6593	859·1705
87	·1816	211·8675.	9	671·8675.	·8271	87	87	·6506	886·8298
87	·1729	240·0404	30	640·0404	·8358	87	88	·6418	914·4804
87	·1642	268·2046	1	608·2046	·8445	87	86	·6332	942·1222
88	·1555	296·3601	2	576·3601	·8533	88	87	·6245	969·7554
86	·1467	324·5068	3	544·5068	·8619	86	88	·6157	110997·3799
88	·1381	352·6449	4	512·6449	·8707	88	86	·6071	111024·9950
87	·1293	380·7742	35	480·7742	·8794	87	87	·5984	052·6027
86	·1206	408·8948	6	448·8948	·8880	86	87	·5897	080·2011
88	·1120	437·0068	7	417·0068	·8968	88	87	·5810	107·7908
87	·1032	465·1100	8	385·1100	·9055	87	88	·5722	135·3718
86	·0945	493·2045	9	353·2045	·9141	86	86	·5636	162·9440
88	·0859	521·2904	40	321·2904	·9229	88	87	·5549	190·5076
88	·0771	549·3675.	1	289·3675.	·9317	88	87	·5462	218·0625
87	·0683	577·4358	2	257·4358	·9404	87	87	·5375	245·6087
86	·0596	605·4954	3	225·4954	·9490	86	87	·5288	273·1462
87	·0510	633·5464	4	193·5464	·9577	87	87	·5201	300·6750
88	·0423	661·5887	45	161·5887	·9665	88	87	·5114	328·1951
86	·0335	689·6222	6	129·6222	·9751	86	86	·5027	355·7065.
87	·0249	717·6471	7	097·6471	·9838	87	87	·4941	383·2092
88	·0162	745·6633	8	065·6633	31·9926	88	88	·4853	410·7033
87	28·0074	773·6707	9	033·6707	32·0013	88	87	·4766	438·1886
87	27·9987	801·6694	50	96001·6694	·0100	87	87	·4679	465·6652
87	·9900	829·6594	1	95969·6594	·0187	87	87	·4592	493·1331
87	·9813	857·6407	2	937·6407	·0274	87	86	·4506	520·5923
87	·9726	885·6133	3	905·6133	·0361	87	88	·4418	548·0429
87	·9639	913·5772	4	873·5772	·0448	87	86	·4332	575·4847
87	·9552	941·5324	55	841·5324	·0535	87	88	·4244	602·9179
87	·9465	969·4789	6	809·4789	·0622	87	86	·4158	630·3423
88	·9378	109997·4167	7	777·4167	·0710	88	88	·4070	657·7581
86	·9290	110025·3457	8	745·3457	·0796	88	86	·3984	685·1651
88	·9204	053·2661	9	713·2661	32·0884	88	87	27·3897	712·5635
	27·9116	110081·1777	60	95681·1777					111739·9532

′	−4°.	Diff.	Δ².	Δ².	Diff.	5°.	′	−5°.	Diff.	Δ².
	′	″			″	″		″	″	
0	95681·1777		86	88		111739·9532	0	93739·9532		88
		32·0970			27·3809				32·6191	
1	649·0807	·1057	87	86	·3723	767·3341	1	707·3341	·6277	86
2	616·9750.	·1145	88	86	·3637	794·7064	2	674·7064	·6363	86
3	584·8605	·1232	87	88	·3549	822·0701	3	642·0701	·6451	88
4	552·7373	·1318	86	87	·3462	849·4250.	4	609·4250.	·6538	87
5	520·6055.	·1406	88	87	·3375	876·7712	5	576·7712	·6625	87
6	488·4649	·1492	86	87	·3288	904·1087	6	544·1087	·6712	87
7	456·3157	·1580	88	87	·3201	931·4375	7	511·4375	·6799	87
8	424·1577	·1667	87	86	·3115	958·7576	8	478·7576	·6885	86
9	391·9910	·1754	87	88	·3027	111986·0691	9	446·0691	·6973	88
10	359·8156	·1841	87	86	·2941	112213·3718	10	413·3718	·7059	86
1	327·6315.	·1928	87	87	·2854	040·6659	1	380·6659	·7146	87
2	295·4387	·2015	87	88	·2766	067·9513	2	347·9513	·7234	88
3	263·2372	·2102	87	86	·2680	095·2279	3	315·2279	·7320	86
4	231·0270	·2189	87	87	·2593	122·4959	4	282·4959	·7407	87
15	198·8081	·2276	87	87	·2506	149·7552	15	249·7552	·7494	87
6	166·5805	·2363	87	87	·2419	177·0058	6	217·0058	·7581	87
7	134·3442	·2450	87	86	·2333	204·2477	7	184·2477	·7667	86
8	102·0992	·2538	88	88	·2245	231·4810	8	151·4810	·7755	88
9	069·8454	·2624	86	86	·2159	258·7055	9	118·7055	·7841	86
20	037·5830	·2711	87	88	·2071	285·9214	20	085·9214	·7929	88
1	95005·3119	·2798	87	86	·1985	313·1285.	1	053·1285.	·8015	86
2	94973·0321	·2885	87	87	·1898	340·3270	2	93020·3270	·8102	87
3	940·7436	·2973	88	87	·1811	367·5168	3	92987·5168	·8189	87
4	908·4463	·3059	86	87	·1724	394·6979	4	954·6979	·8276	87
25	876·1404	·3146	87	87	·1637	421·8703	25	921·8703	·8363	87
6	843·8258	·3233	87	87	·1550	449·0340	6	889·0340	·8450	87
7	811·5025	·3320	87	86	·1464	476·1890	7	856·1890	·8536	86
8	779·1705.	·3407	87	88	·1376	503·3354	8	823·3354	·8624	88
9	746·8298	·3494	87	86	·1290	530·4730	9	790·4730	·8710	86
30	714·4804	·3582	88	87	·1203	557·6020	30	757·6020	·8797	87
1	682·1222	·3668	86	87	·1116	584·7223	1	724·7223	·8884	87
2	649·7554	·3755	87	87	·1029	611·8339	2	691·8339	·8971	87
3	617·3799	·3843	88	87	·0942	638·9368	3	658·9368	·9058	87
4	584·9956	·3929	86	87	·0855	666·0310	4	626·0310	·9145	87
35	552·6027	·4016	87	86	·0769	693·1165	35	593·1165	·9231	86
6	520·2011	·4103	87	87	·0682	720·1934	6	560·1934	·9318	87
7	487·7908	·4190	87	87	·0595	747·2616	7	527·2616	·9405	87
8	455·3718	·4278	88	87	·0508	774·3211	8	494·3211	·9492	87
9	422·9440	·4364	86	87	·0421	801·3719	9	461·3719	·9579	87
40	390·5076	·4451	87	87	·0334	828·4140	40	428·4140	·9666	87
1	358·0625	·4538	87	86	·0248	855·4474.	1	395·4474.	·9752	86
2	325·6087	·4625	87	88	·0160	882·4722	2	362·4722	·9840	88
3	293·1462	·4712	87	86	27·0074	909·4882	3	329·4882	32·9926	86
4	260·6750	·4799	87	87	26·9987	936·4956	4	296·4956	33·0013	87
45	228·1951	·4886	87	87	·9900	963·4943	45	263·4943	·0100	87
6	195·7065.	·4973	87	86	·9814	112990·4843	6	230·4843	·0186	86
7	163·2092	·5059	86	88	·9726	113017·4657	7	197·4657	·0274	88
8	130·7033	·5147	88	86	·9640	044·4383	8	164·4383	·0360	86
9	098·1886	·5234	87	87	·9553	071·4023	9	131·4023	·0447	87
50	065·6652	·5321	87	87	·9466	098·3576	50	098·3576	·0534	87
1	033·1331	·5408	87	87	·9379	125·3042	1	065·3042	·0621	87
2	94000·5923	·5494	86	86	·9293	152·2421	2	92032·2421	·0707	86
3	93968·0429	·5582	88	88	·9205	179·1714	3	91999·1714	·0795	88
4	935·4847	·5668	86	86	·9119	206·0919	4	966·0919	·0881	86
55	902·9179	·5756	88	87	·9032	233·0038	55	933·0038	·0968	87
6	870·3423	·5842	86	87	·8945	259·9070	6	899·9070	·1055	87
7	837·7581	·5930	88	86	·8859	286·8015	7	866·8015	·1141	86
8	805·1651	·6016	86	88	·8771	313·6874	8	833·6874	·1229	88
9	772·5635		87	86		340·5645	9	800·5645		86
60	93739·9532	32·6103			26·8685	113367·4330	60	91767·4330	33·1315	

Δ².	Diff.	6°	′	−6°.	Diff.	Δ².	Δ².	Diff.	7°.
	″	″		″	″			″	″
87	26·8598	113367·4330	0	91767·4330	33·1402	87	86	26·3396	114963·6698
86	·8512	394·2928	1	734·2928	·1488	86	86	·3310	114990·0094
88	·8424	421·1440	2	701·1440	·1576	88	88	·3222	115016·3404
86	·8338	447·9864	3	667·9864	·1662	86	86	·3136	042·6626
87	·8251	474·8202	4	634·8202	·1749	87	87	·3049	068·9762
87	·8164	501·6453	5	601·6453	·1836	87	86	·2963	095·2811
87	·8077	528·4617	6	568·4617	·1923	87	86	·2877	121·5774
86	·7991	555·2694	7	535·2694	·2009	86	88	·2789	147·8651
87	·7904	582·0685	8	502·0685	·2096	87	86	·2703	174·1440
87	·7817	608·8589	9	468·8589	·2183	87	86	·2617	200·4143
87		635·6406	10	435·6406	·2270	87	87	·2530	226·6760
86	·7730	662·4136	1	402·4136	·2356	86	87	·2443	252·9290
87	·7644	689·1780	2	369·1780	·2443	87	86	·2357	279·1733
87	·7557	715·9337	3	335·9337	·2530	87	87	·2270	305·4090
87	·7470	742·6807	4	302·6807	·2617	87	87	·2183	331·6360
86	·7383	769·4190	15	269·4190	·2703	86	86	·2097	357·8543
88	·7297	796·1487	6	236·1487	·2791	88	86	·2011	384·0640
86	·7209	822·8696	7	202·8696	·2877	86	87	·1924	410·2651
86	·7123	849·5819	8	169·5819	·2963	86	87	·1837	436·4575
88	·7037	876·2856	9	136·2856	·3051	88	86	·1751	462·6412
86	·6863	902·9805	20	102·9805	·3137	86	87	·1664	488·8163
87	·6776	929·6668	1	069·6668	·3224	87	86	·1578	514·9827
86	·6690	956·3444	2	036·3444	·3310	86	87	·1491	541·1405
87	·6603	113983·0134	3	91003·0134	·3397	87	86	·1405	567·2896
87	·6516	114009·6737	4	90969·6737	·3484	87	87	·1318	593·4301
87	·6429	036·3253	25	936·3253	·3571	87	87	·1231	619·5619
87	·6342	062·9682	6	902·9682	·3658	87	86	·1145	645·6850
86	·6256	089·6024	7	869·6024	·3744	86	86	·1059	671·7995
87	·6169	116·2280	8	836·2280	·3831	86	87	·0972	697·9054
87	·6082	142·8449	9	802·8449	·3918	87	87	·0885	724·0026
86		169·4531	30	769·4531	·4004	86	86	·0799	750·0911
87	·5996	196·0527	1	736·0527	·4091	87	87	·0712	776·1710
87	·5909	222·6436	2	702·6436	·4178	87	86	·0626	802·2422
86	·5822	249·2258	3	669·2258	·4264	86	86	·0540	828·3048
87	·5736	275·7994	4	635·7994	·4351	87	87	·0453	854·3588
87	·5649	302·3643	35	602·3643	·4438	87	87	·0366	880·4041
87	·5562	328·9205	6	568·9205	·4525	87	86	·0280	906·4407
86	·5475	355·4680	7	535·4680	·4611	86	87	·0193	932·4687
87	·5389	382·0069	8	502·0069	·4698	87	86	·0107	958·4880
86	·5302	408·5371	9	468·5371	·4784	86	87	26·0020	115984·4987
	·5216								
87		435·0587	40	435·0587	·4871	87	86		116010·5007
87	·5129	461·5716	1	401·5716	·4958	87	87	25·9934	036·4941
87	·5042	488·0758	2	368·0758	·5045	87	86	·9847	062·4788
86	·4955	514·5713	3	334·5713	·5131	86	86	·9761	088·4549
87	·4869	541·0582	4	301·0582	·5218	87	87	·9675	114·4224
86	·4782	567·5364	45	267·5364	·5304	86	87	·9588	140·3812
87	·4696	594·0060	6	234·0060	·5391	87	86	·9501	166·3313
87	·4609	620·4669	7	200·4669	·5478	87	86	·9415	192·2728
87	·4522	646·9191	8	166·9191	·5565	87	87	·9329	218·2057
86	·4435	673·3626	9	133·3626	·5651	86	87	·9242	244·1299
	·4349							·9155	
87	·4262	699·7975	50	099·7975	·5738	87	85	·9070	270·0454
86	·4176	726·2237	1	066·2237	·5824	86	88	·8982	295·9524
87	·4089	752·6413	2	90032·6413	·5911	87	86	·8896	321·8506
87	·4002	779·0502	3	89999·0502	·5998	87	86	·8810	347·7402
86	·3916	805·4504	4	965·4504	·6084	86	86	·8724	373·6212
87	·3829	831·8420	55	931·8420	·6171	86	87	·8637	399·4936
87	·3742	858·2249	6	898·2249	·6258	87	87	·8550	425·3573
86	·3656	884·5991	7	864·5991	·6344	87	86	·8464	451·2123
87	·3569	910·9647	8	830·9647	·6431	86	86	·8378	477·0587
87	26·3482	937·3216	9	797·3216	33·6518	87	86	25·8292	502·8965
		114963·6698	60	89763·6698					116528·7257

−7°.	Diff.	Δ².	Δ².	Diff.	8°.	′	−8°.	Diff.	Δ².
″	″			″	″		″	″	
89763·6698	33·6604	86	87	25·8205	116528·7257	0	87728·7257	34·1795	87
730·0094	·6690	86	87	·8118	554·5462	1	694·5462	·1882	87
696·3404	·6778	88	86	·8032	580·3580	2	660·3580	·1968	86
662·6626	·6864	86	87	·7945	606·1612	3	626·1612	·2055	87
628·9762	·6951	87	85	·7860	631·9557	4	591·9557	·2140	85
595·2811	·7037	86	87	·7773	657·7417	5	557·7417	·2227	87
561·5774	·7123	86	87	·7686	683·5190	6	523·5190	·2314	87
527·8651	·7211	88	86	·7600	709·2876	7	489·2876	·2400	86
494·1440	·7297	86	86	·7514	735·0476	8	455·0476	·2486	86
460·4143	·7383	86	87	·7427	760·7990	9	420·7990	·2573	87
426·6760	·7470	87	86	·7341	786·5417	10	386·5417	·2659	86
392·9290	·7557	87	86	·7255	812·2758	1	352·2758	·2745	86
359·1733	·7643	86	88	·7167	838·0013	2	318·0013	·2833	88
325·4090	·7730	87	85	·7082	863·7180	3	283·7180	·2918	85
291·6360	·7817	87	86	·6996	889·4262	4	249·4262	·3004	86
257·8543	·7903	86	87	·6909	915·1258	15	215·1258	·3091	87
224·0640	·7989	86	87	·6822	940·8167	6	180·8167	·3178	87
190·2651	·8076	87	85	·6737	966·4989	7	146·4989	·3263	85
156·4575	·8163	87	87	·6650	116992·1726	8	112·1726	·3350	87
122·6412	·8249	86	86	·6564	117017·8376	9	077·8376	·3436	86
088·8163	·8336	87	87	·6477	043·4940	20	043·4940	·3523	87
054·9827	·8422	86	87	·6390	069·1417	1	87009·1417	·3610	87
89021·1405	·8509	87	85	·6305	094·7807	2	86974·7807	·3695	85
88987·2896	·8595	86	87	·6218	120·4112	3	940·4112	·3782	87
953·4301	·8682	87	86	·6132	146·0330	4	906·0330	·3868	86
919·5819	·8769	87	86	·6046	171·6462	25	871·6462	·3954	86
885·6850	·8855	86	87	·5959	197·2508	6	837·2508	·4041	87
851·7995	·8941	86	86	·5873	222·8467	7	802·8467	·4127	86
817·9054	·9028	87	86	·5787	248·4340	8	768·4340	·4213	86
784·0026	·9115	87	87	·5700	274·0127	9	734·0127	·4300	87
750·0911	·9201	86	86	·5614	299·5827	30	699·5827	·4386	86
716·1710	·9288	87	86	·5528	325·1441	1	665·1441	·4472	86
682·2422	·9374	86	87	·5441	350·6969	2	630·6969	·4559	87
648·3048	·9460	86	86	·5355	376·2410	3	596·2410	·4645	86
614·3588	·9547	87	86	·5269	401·7765	4	561·7765	·4731	86
580·4041	·9634	87	87	·5183	427·3034	35	527·3034	·4817	86
546·4407	·9720	86	87	·5096	452·8217	6	492·8217	·4904	87
512·4687	·9807	87	86	·5010	478·3313	7	458·3313	·4990	86
478·4880	·9893	86	86	·4924	503·8323	8	423·8323	·5076	86
444·4987	33·9980	87	87	·4837	529·3247	9	389·3247	·5163	87
410·5007	34·0066	86	86	·4751	554·8084	40	854·8084	·5249	86
376·4941	·0153	87	86	·4665	580·2835	1	320·2835	·5335	86
342·4788	·0239	86	86	·4579	605·7500	2	285·7500	·5421	86
308·4549	·0325	86	87	·4492	631·2079	3	251·2079	·5508	87
274·4224	·0412	87	86	·4406	656·6571	4	216·6571	·5594	86
240·3812	·0499	87	86	·4320	682·0977	45	182·0977	·5680	86
206·3313	·0585	86	86	·4234	707·5297	6	147·5297	·5766	86
172·2728	·0671	86	87	·4147	732·9531	7	112·9531	·5853	87
138·2057	·0758	87	86	·4061	758·3678	8	078·3678	·5939	86
104·1299	·0845	87	86	·3975	783·7739	9	043·7739	·6025	86
070·0454	·0930	85	86	·3889	809·1714	50	86009·1714	·6111	86
035·9524	·1018	88	87	·3802	834·5603	1	85974·5603	·6198	87
88001·8506	·1104	86	86	·3716	859·9405	2	939·9405	·6284	86
87967·7402	·1190	86	86	·3630	885·3121	3	905·3121	·6370	86
933·6212	·1276	86	86	·3544	910·6751	4	870·6751	·6456	86
899·4936	·1363	87	86	·3458	936·0295	55	836·0295	·6542	86
865·3573	·1450	87	87	·3371	961·3753	6	801·3753	·6629	87
831·2123	·1536	86	86	·3285	117986·7124	7	766·7124	·6715	86
797·0587	·1622	86	86	·3199	118012·0409	8	732·0409	·6801	86
762·8965	34·1708	86	86	25·3113	037·3608	9	697·3608	34·6887	86
87728·7257					118062·6721	60	85662·6721		

Δ².	Diff.	9°.	′	−9°.	Diff.	Δ².
	″	″		″	″	
86		118062·6721	0	85662·6721		86
	25·3027				34·6973	
87		087·9748	1	627·9748		87
	·2940				·7060	
86		113·2688	2	593·2688		86
	·2854				·7146	
86		138·5542	3	558·5542		86
	·2768				·7232	
86		163·8310	4	523·8310		86
	·2682				·7318	
86		189·0992	5	489·0992		86
	·2596				·7404	
87		214·3588	6	454·3588		87
	·2509				·7491	
86		239·6097	7	419·6097		86
	·2423				·7577	
85		264·8520	8	384·8520		85
	·2338				·7662	
87		290·0858	9	350·0858		87
	·2251				·7749	
87		315·3109	10	315·3109		87
	·2164				·7836	
85		340·5273	1	280·5273		85
	·2079				·7921	
86		365·7352	2	245·7352		86
	·1993				·8007	
87		390·9345	3	210·9345		87
	·1906				·8094	
86		416·1251	4	176·1251		86
	·1820				·8180	
86		441·3071	15	141·3071		86
	·1734				·8266	
85		466·4805	6	106·4805		85
	·1649				·8351	
87		491·6454	7	071·6454		87
	·1562				·8438	
87		516·8016	8	036·8016		87
	·1475				·8525	
85		541·9491	9	85001·9491		85
	·1390				·8610	
86		567·0881	20	84967·0881		86
	·1304				·8696	
87		592·2185	1	932·2185		87
	·1217				·8783	
85		617·3402	2	897·3402		85
	·1132				·8868	
87		642·4534	3	862·4534		87
	·1045				·8955	
86		667·5579	4	827·5579		86
	·0959				·9041	
86		692·6538	25	792·6538		86
	·0873				·9127	
86		717·7411	6	757·7411		86
	·0787				·9213	
86		742·8198	7	722·8198		86
	·0701				·9299	
86		767·8899	8	687·8899		86
	·0615				·9385	
87		792·9514	9	652·9514		87
	·0528				·9472	
85		818·0042	30	618·0042		85
	·0443				·9557	
86		843·0485	1	583·0485		86
	·0357				·9643	
87		868·0842	2	548·0842		87
	·0270				·9730	
85		893·1112	3	513·1112		85
	·0185				·9815	
87		918·1297	4	478·1297		87
	·0098				·9902	
85		943·1395	35	443·1395		85
	25·0013				34·9987	
87		968·1408	6	408·1408		87
	24·9926				35·0074	
86		118993·1334	7	373·1334		86
	·9840				·0160	
86		119018·1174	8	338·1174		86
	·9754				·0246	
85		043·0928	9	303·0928		85
	·9669				·0331	
87		068·0597	40	268·0597		87
	·9582				·0418	
86		093·0179	1	233·0179		86
	·9496				·0504	
86		117·9675	2	197·9675		86
	·9410				·0590	
85		142·9085	3	162·9085		85
	·9325				·0675	
87		167·8410	4	127·8410		87
	·9238				·0762	
86		192·7648	45	092·7648		86
	·9152				·0848	
86		217·6800	6	057·6800		86
	·9066				·0934	
86		242·5866	7	84022·5866		86
	·8980				·1020	
86		267·4846	8	83987·4846		86
	·8894				·1106	
86		292·3740	9	952·3740		86
	·8808				·1192	
85		317·2548	50	917·2548		85
	·8723				·1277	
87		342·1271	1	882·1271		87
	·8636				·1364	
86		366·9907	2	846·9907		86
	·8550				·1450	
86		391·8457	3	811·8457		86
	·8464				·1536	
85		416·6921	4	776·6921		85
	·8379				·1621	
87		441·5300	55	741·5300		87
	·8292				·1708	
86		466·3592	6	706·3592		86
	·8206				·1794	
85		491·1798	7	671·1798		85
	·8121				·1879	
87		515·9919	8	635·9919		87
	·8034				·1966	
86		540·7953	9	600·7953		86
	24·7948				35·2052	
		119565·5901	60	83565·5901		

Δ².	Diff.	9°.
	″	
85		119565·5901
	24·7863	
86		590·3764
	·7777	
86		615·1541
	·7691	
87		639·9232
	·7604	
85		664·6836
	·7519	
86		689·4355
	·7433	
86		714·1788
	·7347	
86		738·9135
	·7261	
85		763·6396
	·7176	
87		788·3572
	·7089	
86		813·0661
	·7003	
85		837·7664
	·6918	
86		862·4582
	·6832	
87		887·1414
	·6745	
85		911·8159
	·6660	
86		936·4818
	·6574	
86		961·1391
	·6488	
86		119985·7878
	·6402	
85		120010·4280
	·6317	
87		035·0596
	·6230	
85		059·6826
	·6145	
86		084·2971
	·6059	
86		108·9030
	·5973	
86		133·5004
	·5887	
86		158·0892
	·5801	
85		182·6694
	·5716	
86		207·2411
	·5630	
86		231·8042
	·5544	
86		256·3587
	·5458	
86		280·9046
	·5372	
86		305·4419
	·5286	
85		329·9706
	·5201	
86		354·4907
	·5115	
86		379·0022
	·5029	
86		403·5050
	·4943	
85		427·9993
	·4858	
87		452·4850
	·4771	
85		476·9621
	·4686	
86		501·4306
	·4600	
85		525·8906
	·4515	
86		550·3421
	·4429	
87		574·7850
	·4342	
85		599·2193
	·4257	
85		623·6451
	·4172	
86		648·0623
	·4086	
86		672·4708
	·4000	
86		696·8707
	·3914	
86		721·2620
	·3828	
85		745·6447
	·3743	
86		770·0188
	·3657	
86		794·3843
	·3571	
85		818·7412
	·3486	
86		843·0895
	·3400	
86		867·4292
	·3314	
85		891·7603
	·3229	
87		916·0828
	·3142	
85		940·3967
	·3057	
85		964·7020
	·2972	
86		120989·0008
	·2886	
86		121013·2910
	24·2800	
		121037·5726

	−10°.	Diff.	Δ²	Δ².	Diff.	11°.	′	−11°.	Diff.	Δ².
	″	″			″	″		″	″	
0	83565·5901		85	85		121037·5704	0	81437·5704		85
1	530·3764	35·2137	86	87	24·2715	061·8419	1	401·8419	35·7285	87
2	495·1541	·2223	86	85	·2628	086·1047	2	366·1047	·7372	85
3	459·9232	·2309	87	85	·2543	110·3590	3	330·3590	·7457	85
4	424·6836	·2396	85	86	·2458	134·6048	4	294·6048	·7542	86
5	389·4355	·2481	86	86	·2372	158·8420	5	258·8420	·7628	86
6	354·1788	·2567	86	86	·2286	183·0706	6	223·0706	·7714	86
7	318·9135	·2653	86	85	·2200	207·2906	7	187·2906	·7800	85
8	283·6396	·2739	85	85	·2115	231·5021	8	151·5021	·7885	85
9	248·3572	·2824	87	86	·2030	255·7051	9	115·7051	·7970	86
		·2911			·1944				·8056	
10	213·0661		86	86		279·8995.	10	079·8995.		86
1	177·7664	·2997	85	86	·1858	304·0853	1	044·0853	·8142	86
2	142·4582	·3082	86	85	·1772	328·2625	2	81008·2625	·8228	85
3	107·1414	·3168	87	86	·1687	352·4312	3	80972·4312	·8313	86
4	071·8159	·3255	85	85	·1601	376·5913	4	936·5913	·8399	85
5	036·4819	·3340	86	86	·1516	400·7429	15	900·7429	·8484	86
6	83001·1393	·3426	86	85	·1430	424·8859	6	864·8859	·8570	85
7	82965·7881	·3512	86	86	·1345	449·0204	7	829·0204	·8655	86
8	930·4283	·3598	85	85	·1259	473·1463	8	793·1463	·8741	85
9	895·0600	·3683	87	87	·1174	497·2637	9	757·2637	·8826	87
		·3770			·1087				·8913	
10	859·6830		85	85		521·3724	20	721·3724		85
1	824·2975	·3855	86	85	·1002	545·4726	1	685·4726	·8998	85
2	788·9034	·3941	86	86	·0917	569·5643	2	649·5643	·9083	86
3	753·5007	·4027	86	86	·0831	593·6474	3	613·6474	·9169	86
4	718·0894	·4113	86	84	·0745	617·7219	4	577·7219	·9255	84
15	682·6695	·4199	85	87	·0661	641·7880	25	541·7880	·9339	87
6	647·2411	·4284	86	85	·0574	665·8454	6	505·8454	·9426	85
7	611·8041	·4370	86	85	·0489	689·8943	7	469·8943	·9511	85
8	576·3585	·4456	86	86	·0404	713·9347	8	433·9347	·9596	86
9	540·9043	·4542	86	86	·0318	737·9665.	9	397·9665.	·9682	86
		·4628			·0232				·9768	
30	505·4415		86	85		761·9897	30	361·9897		85
1	469·9701	·4714	85	86	·0147	786·0044	1	326·0044	·9853	86
2	434·4902	·4799	86	85	24·0061	810·0105	2	290·0105	35·9939	85
3	399·0017	·4885	86	86	23·9976	834·0081	3	254·0081	36·0024	86
4	363·5046	·4971	86	85	·9890	857·9971	4	217·9971	·0110	85
35	327·9989	·5057	85	86	·9805	881·9776	35	181·9776	·0195	86
6	292·4847	·5142	87	85	·9719	905·9495	6	145·9495	·0281	85
7	256·9618	·5229	85	86	·9634	929·9129	7	109·9129	·0366	86
8	221·4304	·5314	86	85	·9548	953·8677	8	073·8677	·0452	85
9	185·8904	·5400	85	85	·9463	121977·8140	9	037·8140	·0537	85
		·5485			·9378				·0622	
40	150·3419		86	86		122001·7518	40	80001·7518		86
1	114·7848	·5571	87	86	·9292	025·6810	1	79965·6810	·0708	86
2	079·2190	·5658	85	85	·9206	049·6016	2	929·6016	·0794	85
3	043·6447	·5743	85	85	·9121	073·5137	3	893·5137	·0879	85
4	82008·0619	·5828	86	86	·9036	097·4173	4	857·4173	·0964	86
45	81972·4705.	·5914	86	85	·8950	121·3123	45	821·3123	·1050	85
6	936·8705.	·6000	86	85	·8865	145·1988	6	785·1988	·1135	85
7	901·2619	·6086	86	86	·8780	169·0768	7	749·0768	·1220	86
8	865·6447	·6172	85	86	·8694	192·9462	8	712·9462	·1306	86
9	830·0190	·6257	86	85	·8608	216·8070	9	676·8070	·1392	85
		·6343			·8523				·1477	
50	794·3847		86	86		240·6593	50	640·6593		86
1	758·7418	·6429	85	84	·8437	264·5030	1	604·5030	·1563	84
2	723·0904	·6514	86	86	·8353	288·3383	2	568·3383	·1647	86
3	687·4304	·6600	86	86	·8267	312·1650.	3	532·1650.	·1733	86
4	651·7618	·6686	85	85	·8181	335·9831	4	495·9831	·1819	85
55	616·0847	·6771	87	85	·8096	359·7927	55	459·7927	·1904	85
6	580·3989	·6858	85	86	·8011	383·5938	6	423·5938	·1989	86
7	544·7046	·6943	85	85	·7925	407·3863	7	387·3863	·2075	85
8	509·0018	·7028	86	85	·7840	431·1703	8	351·1703	·2160	85
9	473·2904	·7114	86	86	·7755	454·9458	9	314·9458	·2245	86
60	81437·5704	35·7200			23·7669	122478·7127	60	79278·7127	36·2331	

Δ².	Diff.	12°.	,	−12°.	Diff.	Δ².
	"	"		"	"	
86	23·7583	122478·7127	0	79278·7127	36·2417	86
84	·7499	502·4710	1	242·4710	·2501	84
86	·7413	526·2209	2	206·2209	·2587	86
85	·7328	549·9622	3	169·9622	·2672	85
86	·7242	573·6950.	4	133·6950.	·2758	86
85	·7157	597·4192	5	097·4192	·2843	85
85	·7072	621·1349	6	061·1349	·2928	85
85	·6987	644·8421	7	79024·8421	·3013	85
86	·6901	668·5408	8	78988·5408	·3099	86
86	·6815	692·2309	9	952·2309	·3185	86
84	·6731	715·9124	10	915·9124	·3269	84
86	·6645	739·5855	1	879·5855	·3355	86
85	·6560	763·2500	2	843·2500	·3440	85
85	·6475	786·9060	3	806·9060	·3525	85
86	·6389	810·5535.	4	770·5535.	·3611	86
85	·6304	834·1924	15	734·1924	·3696	85
85	·6219	857·8228	6	697·8228	·3781	85
86	·6133	881·4447	7	661·4447	·3867	86
84	·6049	905·0580	8	625·0580	·3951	84
86	·5963	928·6629	9	588·6629	·4037	86
86	·5877	952·2592	20	552·2592	·4123	86
84	·5793	975·8469	1	515·8469	·4207	84
86	·5707	122999·4262	2	479·4262	·4293	86
85	·5622	123022·9969	3	442·9969	·4378	85
85	·5537	046·5591	4	406·5591	·4463	85
86	·5451	070·1128	25	370·1128	·4549	86
84	·5367	093·6579	6	333·6579	·4633	84
86	·5281	117·1946	7	297·1946	·4719	86
85	·5196	140·7227	8	260·7227	·4804	85
85	·5111	164·2423	9	224·2423	·4889	85
86	·5025	187·7534	30	187·7534	·4975	86
85	·4940	211·2559	1	151·2559	·5060	85
84	·4856	234·7499	2	114·7499	·5144	84
86	·4770	258·2355.	3	078·2355.	·5230	86
85	·4685	281·7125.	4	041·7125.	·5315	85
86	·4599	305·1810	35	78005·1810	·5401	86
85	·4514	328·6409	6	77968·6409	·5486	85
84	·4430	352·0923	7	932·0923	·5570	84
86	·4344	375·5353	8	895·5353	·5656	86
85	·4259	398·9697	9	858·9697	·5741	85
85	·4174	422·3956	40	822·3956	·5826	85
86	·4088	445·8130	1	785·8130	·5912	86
84	·4004	469·2218	2	749·2218	·5996	84
85	·3919	492·6222	3	712·6222	·6081	85
86	·3833	516·0141	4	676·0141	·6167	86
85	·3748	539·3974	45	639·3974	·6252	85
85	·3663	562·7722	6	602·7722	·6337	85
85	·3578	586·1385	7	566·1385	·6422	85
85	·3493	609·4963	8	529·4963	·6507	85
85	·3408	632·8456	9	492·8456	·6592	85
85	·3323	656·1864	50	456·1864	·6677	85
86	·3237	679·5187	1	419·5187	·6763	86
84	·3153	702·8424	2	382·8424	·6847	84
86	·3067	726·1577	3	346·1577	·6933	86
84	·2983	749·4644	4	309·4644	·7017	84
86	·2897	772·7627	55	272·7627	·7103	86
85	·2812	796·0524	6	236·0524	·7188	85
84	·2728	819·3336	7	199·3336	·7272	84
86	·2642	842·6064	8	162·6064	·7358	86
85	23·2557	865·8706	9	125·8706	36·7443	85
		123889·1263	60	77089·1263		

Δ²	Diff.	13°
	"	,
85	23·2472	123885·7283
85	·2387	912·5[illegible]
84	·2303	939·[illegible]
86	·2217	928·[illegible]
85	·2132	123983·[illegible]
85	·2047	124005·[illegible]
85	·1962	[illegible]
85	·1877	051·[illegible]
85	·1792	074·[illegible]
85	·1707	096·[illegible]
85	·1622	121·[illegible]
84	·1538	144·[illegible]
86	·1452	167·[illegible]
85	·1367	190·[illegible]
84	·1283	213·[illegible]
86	·1197	236·[illegible]
84	·1113	260·[illegible]
86	·1027	283·[illegible]
84	·0943	306·[illegible]
85	·0858	329·[illegible]
86	·0772	352·[illegible]
84	·0688	375·[illegible]
85	·0603	398·[illegible]
85	·0518	421·[illegible]
85	·0433	444·[illegible]
84	·0349	467·[illegible]
86	·0263	490·[illegible]
84	·0179	513·[illegible]
86	·0093	536·[illegible]
84	23·0009	559·[illegible]
85	22·9924	582·[illegible]
85	·9839	605·[illegible]
84	·9755	628·[illegible]
86	·9669	651·[illegible]
85	·9584	674·[illegible]
84	·9500	697·[illegible]
85	·9415	720·[illegible]
85	·9330	743·[illegible]
84	·9246	766·[illegible]
86	·9160	789·[illegible]
84	·9076	812·[illegible]
85	·8991	835·[illegible]
85	·8906	858·[illegible]
85	·8821	881·[illegible]
84	·8737	903·[illegible]
85	·8652	926·[illegible]
85	·8567	949·[illegible]
85	·8482	972·[illegible]
84	·8398	124995·[illegible]
85	·8313	125018·[illegible]
85	·8228	041·[illegible]
85	·8143	063·[illegible]
84	·8059	086·[illegible]
85	·7974	109·[illegible]
85	·7889	132·[illegible]
84	·7804	155·[illegible]
84	·7720	177·[illegible]
86	·7636	200·[illegible]
84	·7550	223·[illegible]
84	22·7466	246·[illegible]
		125268·[illegible]

− 13°.	Diff.	Δ².	Δ².	Diff.	14°.	′	−14°.	Diff.	Δ².
″	″			″	″		″	″	
77089·1263	36·7528	85	85	22·7381	125268·9300	0	74868·9300	37·2619	85
052·3735	·7613	85	85	·7296	291·6681	1	831·6681	·2704	85
77015·6122	·7697	84	84	·7212	314·3977	2	794·3977	·2788	84
76978·8425.	·7783	86	85	·7127	337·1189	3	757·1189	·2873	85
942·0642	·7868	85	84	·7043	359·8316	4	719·8316	·2957	84
905·2774	·7953	85	85	·6958	382·5359	5	682·5359	·3042	85
868·4821	·8038	85	85	·6873	405·2317	6	645·2317	·3127	85
831·6783	·8123	85	85	·6788	427·9190	7	607·9190	·3212	85
794·8660	·8208	85	84	·6704	450·5978	8	570·5978	·3296	84
758.0452	·8293	85	85	·6619	473·2682	9	533·2682	·3381	85
721·2159	·8378	85	84	·6535	495·9301	10	495·9301	·3465	84
684·3781	·8462	84	85	·6450	518·5836	1	458·5836	·3550	85
647·5319	·8548	86	84	·6366	541·2286	2	421·2286	·3634	84
610·6771	·8633	85	85	·6281	563·8652	3	383·8652	·3719	85
573·8138	·8717	84	85	·6196	586·4933	4	346·4933	·3804	85
536·9421	·8803	86	84	·6112	609·1129	15	309·1129	·3888	84
500·0618	·8887	84	85	·6027	631·7241	6	271·7241	·3973	85
463·1731	·8973	86	85	·5942	654·3268	7	234·3268	·4058	85
426·2758	·9057	84	84	·5858	676·9210	8	196·9210	·4142	84
389·3701	·9142	85	84	·5774	699·5068	9	159·5068	·4226	84
352·4559	·9228	86	85	·5689	722·0842	20	122·0842	·4311	85
315·5331	·9312	84	85	·5604	744·6531	1	084·6531	·4396	85
278·6019	·9397	85	84	·5520	767·2135	2	047·2135	·4480	84
241·6622	·9482	85	85	·5435	789·7655	3	74009·7655	·4565	85
204·7140	·9567	85	84	·5351	812·3090	4	73972·3090	·4649	84
167·7573	·9651	84	85	·5266	834·8441	25	934·8441	·4734	85
130·7922	·9737	86	84	·5182	857·3707	6	897·3707	·4818	84
093·8185	·9821	84	85	·5097	879·8889	7	859·8889	·4903	85
056·8364	·9907	86	84	·5013	902·3986	8	822·3986	·4987	84
76019·8457	36·9991	84	85	·4928	924·8999	9	784·8999	·5072	85
75982·8466	37·0076	85	84	·4844	947·3927	30	747·3927	·5156	84
945·8390	·0161	85	85	·4759	969·8771	1	709·8771	·5241	85
908·8229	·0245	84	84	·4675	125992·3530	2	672·3530	·5325	84
871·7984	·0331	86	85	·4590	126014·8205	3	634·8205	·5410	85
834·7653	·0416	85	84	·4506	037·2795	4	597·2795	·5494	84
797·7237	·0500	84	84	·4422	059·7301	35	559·7301	·5578	84
760·6737	·0585	85	85	·4337	082·1723	6	522·1723	·5663	85
723·6152	·0670	85	85	·4252	104·6060	7	484·6060	·5748	85
686·5482	·0754	84	84	·4168	127·0312	8	447·0312	·5832	84
649·4728	·0840	86	84	·4084	149·4480	9	409·4480	·5916	84
612·3888	·0924	84	85	·3999	171·8564	40	371·8564	·6001	85
575·2964	·1009	85	84	·3915	194·2563	1	334·2563	·6085	84
538·1955.	·1094	85	85	·3830	216·6478	2	296·6478	·6170	85
501·0861	·1179	85	84	·3746	239·0308	3	259·0308	·6254	84
463·9682	·1263	84	84	·3662	261·4054	4	221·4054	·6338	84
426·8419	·1348	85	85	·3577	283·7716	45	183·7716	·6423	85
389·7071	·1433	85	84	·3493	306·1293	6	146·1293	·6507	84
352·5638	·1518	85	85	·3408	328·4786	7	108·4786	·6592	85
315·4120	·1602	84	84	·3324	350·8194	8	070·8194	·6676	84
278·2518	·1687	85	84	·3240	373·1518	9	73033·1518	·6760	84
241·0831	·1772	85	84	·3156	395·4758	50	72995·4758	·6844	84
203·9059	·1857	85	85	·3071	417·7914	1	957·7914	·6929	85
166·7202	·1941	84	85	·2986	440·0985.	2	920·0985.	·7014	85
129·5261	·2026	85	83	·2903	462·3971	3	882·3971	·7097	83
092·3235.	·2111	85	85	·2818	484·6874	4	844·6874	·7182	85
055·1124	·2196	85	84	·2734	506·9692	55	806·9692	·7266	84
75017·8928	·2280	84	85	·2649	529·2426	6	769·2426	·7351	85
74980·6648	·2364	84	84	·2565	551·5075.	7	731·5075.	·7435	84
943·4284	·2450	86	85	·2480	573·7640	8	693·7640	·7520	85
906·1834	37·2534	84	83	22·2397	596·0120	9	656·0120	37·7603	83
74868·9300					126618·2517	60	72618·2517		

Δ°.	Diff.	15°.	′	−15°.	Diff.	Δ°.	Δ°.	Diff.	16°.
	″	″		″	″			″	″
85		126618·2517	0	72618·2517		85	83		127937·2287
	22·2312				37·7688			21·7267	
84		640·4829	1	580·4829		84	84		958·9554
	·2228				·7772			·7183	
84		662·7057	2	542·7057		84	84		127980·6737
	·2144				·7856			·7099	
85		684·9201	3	504·9201		85	84		128002·3836
	·2059				·7941			·7015	
84		707·1260	4	467·1260		84	83		024·0851
	·1975				·8025			·6932	
84		729·3235.	5	429·3235.		84	85		045·7783
	·1891				·8109			·6847	
85		751·5126	6	391·5126		85	83		067·4630
	·1806				·8194			·6764	
83		773·6932	7	353·6932		83	84		089·1394
	·1723				·8277			·6680	
85		795·8655.	8	315·8655.		85	84		110·8074
	·1638				·8362			·6596	
85		818·0293	9	278·0293		85	84		132·4670
	·1553				·8447			·6512	
83		840·1846	10	240·1846		83	83		154·1182
	·1470				·8530			·6429	
85		862·3316	1	202·3316		85	85		175·7611
	·1385				·8615			·6344	
84		884·4701	2	164·4701		84	83		197·3955·
	·1301				·8699			·6261	
84		906·6002	3	126·6002		84	84		219·0216
	·1217				·8783			·6177	
84		928·7219	4	088·7219		84	84		240·6393
	·1133				·8867			·6093	
85		950·8352	15	050·8352		85	84		262·2486
	·1048				·8952			·6009	
83		972·9400	6	72012·9400		83	83		283·8495
	·0965				·9035			·5926	
85		126995·0365.	7	71975·0365.		85	84		305·4421
	·0880				·9120			·5842	
84		127017·1245.	8	937·1245.		84	84		327·0263
	·0796				·9204			·5758	
84		039·2041	9	899·2041		84	84		348·6021
	·0712				·9288			·5674	
84		061·2753	20	861·2753		84	83		370·1695
	·0628				·9372			·5591	
85		083·3381	1	823·3381		85	84		391·7286
	·0543				·9457			·5507	
83		105·3924	2	785·3924		83	84		413·2793
	·0460				·9540			·5423	
85		127·4384	3	747·4384		85	83		434·8216
	·0375				·9625			·5340	
84		149·4759	5	709·4759		84	85		456·3556
	·0291				·9709			·5255	
84		171·5050.	25	671·5050.		84	83		477·8811
	·0207				·9793			·5172	
84		193·5257	6	633·5257		84	84		499·3983
	·0123				·9877			·5088	
85		215·5380	7	595·5380		85	83		520·9071
	22·0038				37·9962			·5005	
83		237·5418	8	557·5418		83	84		542·4076
	21·9955				38·0045			·4921	
85		259·5373	9	519·5373		85	84		563·8997
	·9870				·0130			·4837	
83		281·5243	30	481·5243		83	83		585·3834
	·9787				·0213			·4754	
85		303·5030	1	443·5030		85	84		606·8588
	·9702				·0298			·4670	
83		325·4732	2	405·4732		83	84		628·3258
	·9619				·0381			·4586	
85		347·4351	3	367·4351		85	84		649·7844
	·9534				·0466			·4502	
84		369·3885.	4	329·3885.		84	83		671·2346
	·9450				·0550			·4419	
84		391·3335	35	291·3335		84	83		692·6765
	·9366				·0634			·4336	
84		413·2701	6	253·2701		84	85		714·1101
	·9282				·0718			·4251	
84		435·1983	7	215·1983		84	83		735·5352
	·9198				·0802			·4168	
84		457·1181	8	177·1181		84	83		756·9520
	·9114.				·0886			·4085	
84		479·0295.	9	139·0295.		84	84		778·3605.
	·9030				·0970			·4001	
84		500·9325	40	100·9325		84	84		799·7606
	·8946				·1054			·3917	
84		522·8271	1	062·8271		84	83		821·1523
	·8862				·1138			·3834	
84		544·7133	2	71024·7133		84	84		842·5357
	·8778				·1222			·3750	
85		566·5911	3	70986·5911		85	84		863·9107
	·8693				·1307			·3666	
83		588·4604	4	948·4604		83	83		885·2773
	·8610				·1390			·3583	
84		610·3214	45	910·3214		84	84		906·6356
	·8526				·1474			·3499	
84		632·1740	6	872·1740		84	83		927·9855
	·8442				·1558			·3416	
84		654·0182	7	834·0182		84	84		949·3271
	·8358				·1642			·3332	
84		675·8540	8	795·8540		84	83		970·6603
	·8274				·1726			·3249	
84		697·6814	9	757·6814		84	84		128991·9852
	·8190				·1810			·3165	
84		719·5004	50	719·5004		84	83		129013·3017
	·8106				·1894			·3082	
84		741·3110	1	681·3110		84	84		034·6099
	·8022				·1978			·2998	
84		763·1132	2	643·1132		84	84		055·9097
	·7938				·2062			·2914	
84		784·9070	3	604·9070		84	83		077·2011
	·7854				·2146			·2831	
83		806·6924	4	566·6924		83	83		098·4842
	·7771				·2229			·2748	
85		828·4695.	55	528·4695.		85	84		119·7590
	·7686				·2314			·2664	
84		850·2381	6	490·2381		84	83		141·0254
	·7602				·2398			·2581	
83		871·9983	7	451·9983		83	84		162·2835.
	·7519				·2481			·2497	
84		893·7502	8	413·7502		84	83		183·5332
	·7435				·2565			·2414	
85		915·4937	9	375·4937		85	84		204·7746
	21·7350				38·2650			21·2330	
		127937·2287	60	70337·2287					129226·0076

′	−16°.	Diff.	Δ².	Δ².	Diff.	17°.	′	−17°.	Diff.	Δ².
	″	″			″					
0	70337·2287		83	83		129226·0076	0	68026·0076		83
1	298·9554	38·2735	84	84	21·2247	247·2323	1	67987·2323	38·7753	84
2	260·6737	·2817	84	83	·2163	268·4486	2	948·4486	·7837	83
3	222·3836	·2901	84	83	·2080	289·6566	3	909·6566	·7920	83
4	184·0851	·2985	83	84	·1997	310·8563	4	870·8563	·8003	84
5	145·7783	·3068	85	84	·1913	332·0476	5	832·0476	·8087	84
6	107·4630	·3153	83	83	·1829	353·2305·	6	793·2305·	·8171	83
7	069·1394	·3236	84	83	·1746	374·4051	7	754·4051	·8254	83
8	70030·8074	·3320	84	84	·1663	395·5714	8	715·5714	·8337	84
9	69992·4670	·3404	84	83	·1579	416·7293	9	676·7293	·8421	83
		·3488			·1496				·8504	
10	954·1182		83	83		437·8789	10	637·8789		83
1	915·7611	·3571	85	84	·1413	459·0202	1	599·0202	·8587	84
2	877·3955·	·3656	83	83	·1329	480·1531	2	560·1531	·8671	83
3	839·0216	·3739	84	83	·1246	501·2777	3	521·2777	·8754	83
4	800·6393	·3823	84	84	·1163	522·3940	4	482·3940	·8837	84
15	762·2486	·3907	84	83	·1079	543·5019	15	443·5019	·8921	83
6	723·8495	·3991	83	84	·0996	564·6015·	6	404·6015·	·9004	84
7	685·4421	·4074	84	83	·0912	585·6927	7	365·6927	·9088	83
8	647·0263	·4158	84	83	·0829	606·7756	8	326·7756	·9171	83
9	608·6021	·4242	84	83	·0746	627·8502	9	287·8502	·9254	83
		·4326			·0663				·9337	
20	570·1695		83	84		648·9165	20	248·9165		84
1	531·7286	·4409	84	83	·0579	669·9744	1	209·9744	·9421	83
2	493·2793	·4493	84	83	·0496	691·0240	2	171·0240	·9504	83
3	454·8216	·4577	83	84	·0413	712·0653	3	132·0653	·9587	84
4	416·3556	·4660	85	83	·0329	733·0982	4	093·0982	·9671	83
25	377·8811	·4745	83	83	·0246	754·1228	25	054·1228	·9754	83
6	339·3983	·4828	84	83	·0163	775·1391	6	67015·1391	·9837	83
7	300·9071	·4912	83	84	21·0080	796·1471	7	66976·1471	38·9920	84
8	262·4076	·4995	84	83	20·9996	817·1467	8	937·1467	39·0004	83
9	223·8997	·5079	84	83	·9913	838·1380	9	898·1380	·0087	83
		·5163			·9830				·0170	
30	185·3834		83	83		859·1210	30	859·1210		83
1	146·8588	·5246	84	84	·9747	880·0957	1	820·0957	·0253	84
2	108·3258	·5330	84	83	·9663	901·0620	2	781·0620	·0337	83
3	069·7844	·5414	84	83	·9580	922·0200	3	742·0200	·0420	83
4	69031·2346	·5498	83	83	·9497	942·9697	4	702·9697	·0503	83
35	68992·6765	·5581	83	83	·9414	963·9111	35	663·9111	·0586	83
6	954·1101	·5664	85	84	·9331	129984·8442	6	624·8442	·0669	84
7	915·5352	·5749	83	82	·9247	130005·7689	7	585·7689	·0753	82
8	876·9520	·5832	83	84	·9165	026·6854	8	546·6854	·0835	84
9	838·3605·	·5915	84	83	·9081	047·5935·	9	507·5935·	·0919	83
		·5999			·8998				·1002	
40	799·7606		84	83		068·4933	40	468·4933		83
1	761·1523	·6083	83	84	·8915	089·3848	1	429·3848	·1085	84
2	722·5357	·6166	84	82	·8831	110·2679	2	390·2679	·1169	82
3	683·9107	·6250	84	84	·8749	131·1428	3	351·1428	·1251	84
4	645·2773	·6334	83	83	·8665	152·0093	4	312·0093	·1335	83
45	606·6356	·6417	84	82	·8582	172·8675	45	272·8675	·1418	82
6	567·9855	·6501	83	84	·8500	193·7175·	6	233·7175·	·1500	84
7	529·3271	·6584	84	84	·8416	214·5591	7	194·5591	·1584	84
8	490·6603	·6668	83	82	·8332	235·3923	8	155·3923	·1668	82
9	451·9852	·6751	84	83	·8250	256·2173	9	116·2173	·1750	83
		·6835			·8167				·1833	
50	413·3017		83	83		277·0340	50	077·0340		83
1	374·6099	·6918	84	83	·8084	297·8424	1	66037·8424	·1916	83
2	335·9097	·7002	84	84	·8001	318·6425·	2	65998·6425·	·1999	84
3	297·2011	·7086	83	82	·7917	339·4342	3	959·4342	·2083	82
4	258·4842	·7169	83	84	·7835	360·2177	4	920·2177	·2165	84
55	219·7590	·7252	84	82	·7751	380·9928	55	880·9928	·2249	82
6	181·0254	·7336	83	84	·7669	401·7597	6	841·7597	·2331	84
7	142·2835·	·7419	84	83	·7585	422·5182	7	802·5182	·2415	83
8	103·5332	·7503	83	82	·7502	443·2684	8	763·2684	·2498	82
9	064·7746	·7586	84	84	·7420	464·0104	9	724·0104	·2580	84
60	68026·0076	38·7670			20·7336	130484·7440	60	65684·7440	39·2664	

Δ°.	Diff.	3°.	′	−3°.	Diff.	Δ°.	Δ°.	Diff.	4°.
	″	″		″	″				″
88	28·4255	108391·0638	0	97591·0638	31·5745	88	86		110081·1777
87	·4168	419·4893	1	559·4893	·5832	87	87	27·9030	109·0807
86	·4082	447·9061	2	527·9001	·5918	86	88	·8943	136·9750
88	·3994	476·3143	3	496·3143	·6006	88	87	·8855	164·8605
87	·3907	504·7137	4	464·7137	·6093	87	86	·8768	192·7373
87	·3820	533·1044	5	433·1044	·6180	87	88	·8682	220·6055
87	·3733	561·4864	6	401·4864	·6267	87	86	·8594	248·4649
88	·3645	589·8597	7	369·8597	·6355	88	88	·8508	276·3157
86	·3559	618·2242	8	338·2242	·6441	86	87	·8420	304·1577
88	·3471	646·5801	9	306·5801	·6529	88	87	·8333	331·9910
86		674·9272	10	274·9272	·6615	86	87	·8246	359·8156
88	·3385	703·2657	1	243·2657	·6703	88	87	·8159	387·6315
87	·3297	731·5954	2	211·5954	·6790	87	87	·8072	415·4387
88	·3210	759·9164	3	179·9164	·6878	88	87	·7985	443·2372
86	·3122	788·2286	4	148·2286	·6964	86	87	·7898	471·0270
87	·3036	816·5322	15	116·5322	·7051	87	87	·7811	498·8081
88	·2949	844·8271	6	084·8271	·7139	88	87	·7724	526·5805
86	·2861	873·1132	7	053·1132	·7225	86	87	·7637	554·3442
88	·2775	901·3907	8	97021·3907	·7313	88	88	·7550	582·0992
87	·2687	929·6594	9	96989·6594	·7400	87	86	·7462	609·8454
87	·2600	957·9194	20	957·9194	·7487	87	87	·7376	637·5830
87	·2513	108986·1707	1	926·1707	·7574	87	87	·7289	665·3119
87	·2426	109014·4133	2	894·4133	·7661	87	87	·7202	693·0321
88	·2339	042·6472	3	862·6472	·7749	88	88	·7115	720·7436
86	·2251	070·8723	4	830·8723	·7835	86	86	·7027	748·4463
88	·2165	099·0888	25	799·0888	·7923	88	87	·6941	776·1404
86	·2077	127·2965	6	767·2965	·8009	86	87	·6854	803·8258
88	·1991	155·4956	7	735·4956	·8097	88	87	·6767	831·5025
87	·1903	183·6859	8	703·6859	·8184	87	87	·6680	859·1705
87	·1816	211·8675	9	671·8675	·8271	87	87	·6593	886·8298
87	·1729	240·0404	30	640·0404	·8358	87	88	·6506	914·4804
87	·1642	268·2046	1	608·2046	·8445	87	86	·6418	942·1222
88	·1555	296·3601	2	576·3601	·8533	88	87	·6332	969·7554
86	·1467	324·5068	3	544·5068	·8619	86	88	·6245	110997·3799
88	·1381	352·6449	4	512·6449	·8707	88	86	·6157	111024·9956
87	·1293	380·7742	35	480·7742	·8794	87	87	·6071	052·6027
86	·1206	408·8948	6	448·8948	·8880	86	87	·5984	080·2011
88	·1120	437·0068	7	417·0068	·8968	88	87	·5897	107·7908
87	·1032	465·1100	8	385·1100	·9055	87	88	·5810	135·3718
86	·0945	493·2045	9	353·2045	·9141	86	86	·5722	162·9440
88	·0859	521·2904	40	321·2904	·9229	88	87	·5636	190·5076
88	·0771	549·3675	1	289·3675	·9317	88	87	·5549	218·0625
87	·0683	577·4358	2	257·4358	·9404	87	87	·5462	245·6087
86	·0596	605·4954	3	225·4954	·9490	86	87	·5375	273·1462
87	·0510	633·5464	4	193·5464	·9577	87	87	·5288	300·6750
88	·0423	661·5887	45	161·5887	·9665	88	87	·5201	328·1951
86	·0335	689·6222	6	129·6222	·9751	86	87	·5114	355·7065
87	·0249	717·6471	7	097·6471	·9838	87	86	·5027	383·2092
88	·0162	745·6633	8	065·6633	31·9926	88	88	·4941	410·7033
87	28·0074	773·6707	9	033·6707	32·0013	87	87	·4853	438·1886
87	27·9987	801·6694	50	96001·6694	·0100	87	87	·4766	465·6652
87	·9900	829·6594	1	95969·6594	·0187	87	87	·4679	493·1331
87	·9813	857·6407	2	937·6407	·0274	87	86	·4592	520·5923
87	·9726	885·6133	3	905·6133	·0361	87	88	·4506	548·0429
87	·9639	913·5772	4	873·5772	·0448	87	86	·4418	575·4847
87	·9552	941·5324	55	841·5324	·0535	87	88	·4332	602·9179
87	·9465	969·4789	6	809·4789	·0622	87	86	·4244	630·3423
88	·9378	109997·4167	7	777·4167	·0710	88	88	·4158	657·7581
86	·9290	110025·3457	8	745·3457	·0796	86	86	·4070	685·1651
88	·9204	053·2661	9	713·2661	32·0884	88	87	·3984	712·5635
	27·9116	110081·1777	60	95681·1777				27·3897	111739·9532

′	−4°.	Diff.	Δ².	Δ².	Diff.	5°.	′	−5°.	Diff.	Δ².
	′	″			″	″		″	″	
0	95681·1777	32·0970	86	88	27·3809	111739·9532	0	93739·9532	32·6191	88
1	649·0807	·1057	87	86	·3723	767·3341	1	707·3341	·6277	86
2	616·9750.	·1145	88	86	·3637	794·7064	2	674·7064	·6363	86
3	584·8605	·1232	87	88	·3549	822·0701	3	642·0701	·6451	88
4	552·7373	·1318	86	87	·3462	849·4250.	4	609·4250.	·6538	87
5	520·6055.	·1406	88	87	·3375	876·7712	5	576·7712	·6625	87
6	488·4649	·1492	86	87	·3288	904·1087	6	544·1087	·6712	87
7	456·3157	·1580	88	87	·3201	931·4375	7	511·4375	·6799	87
8	424·1577	·1667	87	86	·3115	958·7576	8	478·7576	·6885	86
9	391·9910	·1754	87	88	·3027	111986·0691	9	446·0691	·6973	88
10	359·8156	·1841	87	86	·2941	112213·3718	10	413·3718	·7059	86
1	327·6315.	·1928	87	87	·2854	040·6659	1	380·6659	·7146	87
2	295·4387	·2015	87	88	·2766	067·9513	2	347·9513	·7234	88
3	263·2372	·2102	87	86	·2680	095·2279	3	315·2279	·7320	86
4	231·0270	·2189	87	87	·2593	122·4959	4	282·4959	·7407	87
15	198·8081	·2276	87	87	·2506	149·7552	15	249·7552	·7494	87
6	166·5805	·2363	87	87	·2419	177·0058	6	217·0058	·7581	87
7	134·3442	·2450	87	86	·2333	204·2477	7	184·2477	·7667	86
8	102·0992	·2538	88	88	·2245	231·4810	8	151·4810	·7755	88
9	069·8454	·2624	86	86	·2159	258·7055	9	118·7055	·7841	86
20	037·5830	·2711	87	88	·2071	285·9214	20	085·9214	·7929	88
1	95005·3119	·2798	87	86	·1985	313·1285.	1	053·1285.	·8015	86
2	94973·0321	·2885	87	87	·1898	340·3270	2	93020·3270	·8102	87
3	940·7436	·2973	88	87	·1811	367·5168	3	92987·5168	·8189	87
4	908·4463	·3059	86	87	·1724	394·6979	4	954·6979	·8276	87
25	876·1404	·3146	87	87	·1637	421·8703	25	921·8703	·8363	87
6	843·8258	·3233	87	87	·1550	449·0340	6	889·0340	·8450	87
7	811·5025	·3320	87	86	·1464	476·1890	7	856·1890	·8536	86
8	779·1705.	·3407	87	88	·1376	503·3354	8	823·3354	·8624	88
9	746·8298	·3494	87	86	·1290	530·4730	9	790·4730	·8710	86
30	714·4804	·3582	88	87	·1203	557·6020	30	757·6020	·8797	87
1	682·1222	·3668	86	87	·1116	584·7223	1	724·7223	·8884	87
2	649·7554	·3755	87	87	·1029	611·8339	2	691·8339	·8971	87
3	617·3799	·3843	88	87	·0942	638·9368	3	658·9368	·9058	87
4	584·9956	·3929	86	87	·0855	666·0310	4	626·0310	·9145	87
35	552·6027	·4016	87	86	·0769	693·1165	35	593·1165	·9231	86
6	520·2011	·4103	87	87	·0682	720·1934	6	560·1934	·9318	87
7	487·7908	·4190	87	87	·0595	747·2616	7	527·2616	·9405	87
8	455·3718	·4278	88	87	·0508	774·3211	8	494·3211	·9492	87
9	422·9440	·4364	86	87	·0421	801·3719	9	461·3719	·9579	87
40	390·5076	·4451	87	87	·0334	828·4140	40	428·4140	·9666	87
1	358·0625	·4538	87	86	·0248	855·4474.	1	395·4474.	·9752	86
2	325·6087	·4625	87	88	·0160	882·4722	2	362·4722	·9840	88
3	293·1462	·4712	87	86	27·0074	909·4882	3	329·4882	32·9926	86
4	260·6750	·4799	87	87	26·9987	936·4956	4	296·4956	33·0013	87
45	228·1951	·4886	87	87	·9900	963·4943	45	263·4943	·0100	87
6	195·7065.	·4973	87	86	·9814	112990·4843	6	230·4843	·0186	86
7	163·2092	·5059	86	88	·9726	113017·4657	7	197·4657	·0274	88
8	130·7033	·5147	88	86	·9640	044·4383	8	164·4383	·0360	86
9	098·1886	·5234	87	87	·9553	071·4023	9	131·4023	·0447	87
50	065·6652	·5321	87	87	·9466	098·3576	50	098·3576	·0534	87
1	033·1331	·5408	87	87	·9379	125·3042	1	065·3042	·0621	87
2	94000·5923	·5494	86	86	·9293	152·2421	2	92032·2421	·0707	86
3	93968·0429	·5582	88	88	·9205	179·1714	3	91999·1714	·0795	88
4	935·4847	·5668	86	86	·9119	206·0919	4	966·0919	·0881	86
55	902·9179	·5756	88	87	·9032	233·0038	55	933·0038	·0968	87
6	870·3423	·5842	86	87	·8945	259·9070	6	899·9070	·1055	87
7	837·7581	·5930	88	86	·8859	286·8015	7	866·8015	·1141	86
8	805·1651	·6016	86	88	·8771	313·6874	8	833·6874	·1229	88
9	772·5635	32·6103	87	86	26·8685	340·5645	9	800·5645	33·1315	86
60	93739·9532					113367·4330	60	91767·4330		

Δ².	Diff.	21°.	,	−21°.	Diff.	Δ².	Δ².	Diff.	22°
	"	"		"	"			"	"
81	19·2449	134082·3929	0	58482·3929	40·7551	81	82	18·7577	135222·6991
82	·2367	101·6378	1	441·6378	·7633	82	80	·7497	241·4568
81	·2286	120·8745	2	400·8745	·7714	81	82	·7415	260·2065
81	·2205	140·1031	3	360·1031	·7795	81	80	·7335	278·9480
82	·2123	159·3236	4	319·3236	·7877	82	81	·7254	297·6815
82	·2041	178·5359	5	278·5359	·7959	82	80	·7174	316·4069
80	·1961	197·7400	6	237·7400	·8039	80	82	·7092	335·1243
82	·1879	216·9361	7	196·9361	·8121	82	81	·7011	353·8335
82	·1797	236·1240	8	156·1240	·8203	82	80	·6931	372·5346
81	·1716	255·3037	9	115·3037	·8284	81	81	·6850	391·2277
81	·1635	274·4753	10	074·4753	·8365	81	81	·6769	409·9127
82	·1553	293·6388	1	58033·6388	·8447	82	81	·6688	428·5896
81	·1472	312·7941	2	57992·7941	·8528	81	81	·6607	447·2584
82	·1390	331·9413	3	951·9413	·8610	82	80	·6527	465·9191
80	·1310	351·0803	4	911·0803	·8690	80	81	·6446	484·5718
82	·1228	370·2113	15	870·2113	·8772	82	81	·6365	503·2164
82	·1146	389·3341	6	829·3341	·8854	82	81	·6284	521·8529
81	·1065	408·4487	7	788·4487	·8935	81	80	·6203	540·4813
81	·0984	427·5552	8	747·5552	·9016	81	81	·6123	559·1016
81	·0903	446·6536	9	706·6536	·9097	81	81	·6042	577·7139
81	·0822	465·7439	20	665·7439	·9178	81	80	·5962	596·3181
82	·0740	484·8261	1	624·8261	·9260	82	82	·5880	614·9143
81	·0659	503·9001	2	583·9001	·9341	81	80	·5800	633·5023
82	·0577	522·9660	3	542·9660	·9423	82	81	·5719	652·0823
80	·0497	542·0237	4	502·0237	·9503	80	80	·5639	670·6542
82	·0415	561·0734	25	461·0734	·9585	82	81	·5558	689·2181
81	·0334	580·1149	6	420·1149	·9666	81	81	·5477	707·7739
82	·0252	599·1483	7	379·1483	·9748	82	80	·5397	726·3216
80	·0172	618·1735	8	338·1735	·9828	80	81	·5316	744·8613
82	·0090	637·1907	9	297·1907	·9910	82	81	·5235	763·3929
81	19·0009	656·1997	30	256·1997	40·9991	81	81	·5154	781·9164
81	18·9928	675·2006	1	215·2006	41·0072	81	80	·5074	800·4318
82	·9846	694·1934	2	174·1934	·0154	82	80	·4994	818·9392
80	·9766	713·1780	3	133·1780	·0234	80	81	·4913	837·4386
82	·9684	732·1546	4	092·1546	·0316	82	81	·4832	855·9299
81	·9603	751·1230	35	051·1230	·0397	81	80	·4752	874·4131
81	·9522	770·0833	6	57010·0833	·0478	81	81	·4671	892·8883
81	·9441	789·0355	7	56969·0355	·0559	81	81	·4590	911·3554
81	·9360	807·9796	8	927·9796	·0640	81	80	·4510	929·8144
81	·9279	826·9156	9	886·9156	·0721	81	80	·4430	948·2654
81	·9198	845·8435	40	845·8435	·0802	81	81	·4349	966·7084
82	·9116	864·7633	1	804·7633	·0884	82	81	·4268	135985·1433
80	·9036	883·6749	2	763·6749	·0964	80	80	·4188	136003·5701
82	·8954	902·5785.	3	722·5785.	·1046	82	80	·4108	021·9889
81	·8873	921·4739	4	681·4739	·1127	81	81	·4027	040·3997
80	·8793	940·3612	45	640·3612	·1207	80	81	·3946	058·8024
82	·8711	959·2405.	6	599·2405.	·1289	82	80	·3866	077·1970
81	·8630	978·1116	7	558·1116	·1370	81	80	·3786	095·5836
81	·8549	134996·9746	8	516·9746	·1451	81	81	·3705	113·9622
81	·8468	135015·8295	9	475·8295	·1532	81	80	·3625	132·3327
81	·8387	034·6763	50	434·6763	·1613	81	81	·3544	150·6952
81	·8306	053·5150	1	393·5150	·1694	81	81	·3463	169·0496
80	·8226	072·3456	2	352·3456	·1774	80	79	·3384	187·3959
82	·8144	091·1682	3	311·1682	·1856	82	81	·3303	205·7343
81	·8063	109·9826	4	269·9826	·1937	81	80	·3223	224·0646
81	·7982	128·7889	55	228·7889	·2018	81	81	·3142	242·3869
81	·7901	147·5871	6	187·5871	·2099	81	80	·3062	260·7011
80	·7821	166·3772	7	146·3772	·2179	80	81	·2981	279·0073
82	·7739	185·1593	8	105·1593	·2261	82	80	·2901	297·3054
80	18·7659	203·9332	9	063·9332	41·2341	80	80	18·2821	315·5955
		135222·6991	60	56022·6991					136333·8776

−22°.	Diff.	Δ².	Δ³.	Diff.	23°.	′	−23°.	Diff.	Δ².
″	″			″	″		″	″	
56022·6991	41·2423	82	80	18·2741	136333·8776	0	53533·8776	41·7259	80
55981·4568	·2503	80	81	·2660	352·1517	1	492·1517	·7340	81
940·2065.	·2585	82	80	·2580	370·4177	2	450·4177	·7420	80
898·9480	·2665	80	81	·2499	388·6757	3	408·6757	·7501	81
857·6815	·2746	81	79	·2420	406·9256	4	366·9256	·7580	79
816·4069	·2826	80	81	·2339	425·1676	5	325·1676	·7661	81
775·1243	·2908	82	81	·2258	443·4015	6	283·4015	·7742	81
733·8335.	·2989	81	79	·2179	461·6273	7	241·6273	·7821	79
692·5346	·3069	80	81	·2098	479·8452	8	199·8452	·7902	81
651·2277	·3150	81	80	·2018	498·0550	9	158·0550	·7982	80
609·9127	·3231	81	80	·1938	516·2568	10	116·2568	·8062	80
568·5896	·3312	81	81	·1857	534·4506	1	074·4506	·8143	81
527·2584	·3393	81	79	·1778	552·6363	2	53032·6363	·8222	79
485·9191	·3473	80	81	·1697	570·8141	3	52990·8141	·8303	81
444·5718	·3554	81	80	·1617	588·9838	4	948·9838	·8383	80
403·2164	·3635	81	81	·1536	607·1455.	15	907·1455.	·8464	81
361·8529	·3716	81	79	·1457	625·2991	6	865·2991	·4543	79
320·4813	·3797	81	81	·1376	643·4448	7	823·4448	·8624	81
279·1016	·3877	80	79	·1297	661·5824	8	781·5824	·8703	79
237·7139	·3958	81	81	·1216	679·7121	9	739·7121	·8784	81
196·3181	·4038	80	80	·1136	697·8337	20	697·8337	·8864	80
154·9143	·4120	82	80	·1056	715·9473	1	655·9473	·8944	80
113·5023	·4200	80	80	·0976	734·0529	2	614·0529	·9024	80
072·0823	·4281	81	81	·0895	752·1505.	3	572·1505.	·9105	81
55030·6542	·4361	80	79	·0816	770·2400	4	530·2400	·9184	79
54989·2181	·4442	81	81	·0735	788·3216	25	488·3216	·9265	81
947·7739	·4523	81	79	·0656	806·3951	6	446·3951	·9344	79
906·3216	·4603	80	81	·0575	824·4607	7	404·4607	·9425	81
864·8613	·4684	81	80	·0495	842·5182	8	362·5182	·9505	80
823·3929	·4765	81	79	·0416	860·5677	9	320·5677	·9584	79
781·9164	·4846	81	81	·0335	878·6093	30	278·6093	·9665	81
740·4318	·4926	80	80	·0255	896·6428	1	236·6428	·9745	80
698·9392	·5006	80	79	·0176	914·6683	2	194·6683	·9824	79
657·4386	·5087	81	81	·0095	932·6859	3	152·6859	·9905	81
615·9299	·5168	81	80	18·0015	950·6954	4	110·6954	41·9985	80
574·4131	·5248	80	80	17·9935	968·6969	35	068·6969	42·0065	80
532·8883	·5329	81	79	·9856	136986·6904	6	52026·6904	·0144	79
491·3554	·5410	81	81	·9775	137004·6760	7	51984·6760	·0225	81
449·8144	·5490	80	80	·9695	022·6535.	8	942·6535.	·0305	80
408·2654	·5570	80	79	·9616	040·6230	9	900·6230	·0384	79
366·7084	·5651	81	81	·9535	058·5846	40	858·5846	·0465	81
325·1433	·5732	81	79	·9456	076·5381	1	816·5381	·0544	79
283·5701	·5812	80	80	·9376	094·4837	2	774·4837	·0624	80
241·9889	·5892	80	80	·9296	112·4213	3	732·4213	·0704	80
200·3997	·5973	81	80	·9216	130·3509	4	690·3509	·0784	80
158·8024	·6054	81	80	·9136	148·2725.	45	648·2725.	·0864	80
117·1970	·6134	80	80	·9056	166·1861	6	606·1861	·0944	80
075·5836	·6214	80	80	·8976	184·0917	7	564·0917	·1024	80
54033·9622	·6295	81	80	·8896	201·9893	8	521·9893	·1104	80
53992·3327	·6375	80	79	·8817	219·8789	9	479·8789	·1183	79
950·6952	·6456	81	80	·8737	237·7606	50	437·7606	·1263	80
909·0496	·6537	81	80	·8657	255·6343	1	395·6343	·1343	80
867·3959	·6616	79	80	·8577	273·5000	2	353·5000	·1423	80
825·7343	·6697	81	79	·8498	291·3577	3	311·3577	·1502	79
784·0646	·6777	80	81	·8417	309·2075.	4	269·2075.	·1583	81
742·3869	·6858	81	79	·8338	327·0492	55	227·0492	·1662	79
700·7011	·6938	80	80	·8258	344·8830	6	184·8830	·1742	80
659·0073	·7019	81	79	·8179	362·7088	7	142·7088	·1821	79
617·3054	·7099	80	81	·8098	380·5267	8	100·5267	·1902	81
575·5955	41·7179	80	79	17·8019	398·3365	9	058·3365	42·1981	79
53533·8776					137416·1384	60	51016·1384		

Δ².	Diff.	24°.	,	−24°.	Diff.	Δ².		Diff.	25°.
	"	"		"	"			"	"
80	17·7939	137416·1384	0	51016·1384	42·2061	80	79	17·3175	138469·7000
79	·7860	433·9323	1	50973·9323	·2140	79	79	·3096	487·0175
81	·7779	451·7183	2	931·7183	·2221	81	79	·3017	504·3271
79	·7700	469·4962	3	889·4962	·2300	79	79	·2938	521·6288
79	·7621	487·2662	4	847·2662	·2379	79	79	·2859	538·9226
81	·7540	505·0283	5	805·0283	·2460	81	80	·2779	556·2085
79	·7461	522·7823	6	762·7823	·2539	79	78	·2701	573·4864
79	·7382	540·5284	7	720·5284	·2618	79	79	·2622	590·7565
80	·7302	558·2666	8	678·2666	·2698	79	80	·2542	608·0187
80	·7222	575·9968	9	635·9968	·2778	80	78	·2464	625·2729
80	·7142	593·7190	10	593·7190	·2858	80	79	·2385	642·5193
79	·7063	611·4332	1	551·4332	·2937	79	80	·2305	659·7578
80	·6983	629·1395	2	509·1395	·3017	80	78	·2227	676·9883
79	·6904	646·8378	3	466·8378	·3096	79	79	·2148	694·2110
80	·6824	664·5282	4	424·5282	·3176	80	79	·2069	711·4258
79	·6745	682·2106	15	382·2106	·3255	79	79	·1990	728·6327
80	·6665	699·8851	6	339·8851	·3335	80	79	·1911	745·8317
80	·6585	717·5516	7	297·5516	·3415	80	79	·1832	763·0228
79	·6506	735·2101	8	255·2101	·3494	79	79	·1753	780·2060
80	·6426	752·8607	9	212·8607	·3574	80	79	·1674	797·3813
79	·6347	770·5033	20	170·5033	·3653	79	79	·1595	814·5487
79	·6268	788·1380	1	128·1380	·3732	79	78	·1517	831·7082
80	·6188	805·7648	2	085·7648	·3812	80	79	·1438	848·8599
80	·6108	823·3836	3	043·3836	·3892	80	79	·1359	866·0037
79	·6029	840·9944	4	50000·9944	·3971	79	79	·1280	883·1396
79	·5950	858·5973	25	49958·5973	·4050	79	79	·1201	900·2676
80	·5870	876·1923	6	916·1923	·4130	80	79	·1122	917·3877
80	·5790	893·7793	7	873·7793	·4210	80	78	·1044	934·4999
79	·5711	911·3583	8	831·3583	·4289	79	79	·0965	951·6043
79	·5632	928·9294	9	788·9294	·4368	79	79	·0886	968·7008
79	·5553	946·4926	30	746·4926	·4447	79	79	·0807	138985·7894
80	·5473	964·0479	1	704·0479	·4527	80	78	·0729	139002·8701
80	·5393	981·5952	2	661·5952	·4607	80	79	·0650	019·9430
79	·5314	137999·1345	3	619·1345	·4686	79	79	·0571	037·0080
79	·5235	138016·6659	4	576·6659	·4765	79	79	·0492	054·0651
80	·5155	034·1894	35	534·1894	·4845	80	78	·0414	071·1143
79	·5076	051·7049	6	491·7049	·4924	79	79	·0335	088·1557
79	·4997	069·2125	7	449·2125	·5003	79	79	·0256	105·1892
79	·4918	086·7122	8	406·7122	·5082	79	79	·0177	122·2148
80	·4838	104·2040	9	364·2040	·5162	80	78	·0099	139·2325
80	·4758	121·6878	40	321·6878	·5242	80	79	17·0020	156·2424
78	·4680	139·1636	1	279·1636	·5320	78	78	16·9942	173·2444
80	·4600	156·6316	2	236·6316	·5400	80	79	·9863	190·2386
79	·4521	174·0916	3	194·0916	·5479	79	79	·9784	207·2249
79	·4442	191·5437	4	151·5437	·5558	79	78	·9706	224·2033
80	·4362	208·9879	45	108·9879	·5638	80	79	·9627	241·1739
78	·4284	226·4241	6	066·4241	·5716	78	78	·9549	258·1366
80	·4204	243·8525	7	49023·8525	·5796	80	79	·9470	275·0915
80	·4124	261·2729	8	48981·2729	·5876	80	79	·9391	292·0385
78	·4046	278·6853	9	938·6853	·5954	78	78	·9313	308·9776
80	·3966	296·0899	50	896·0899	·6034	80	79	·9234	325·9089
79	·3887	313·4865	1	853·4865	·6113	79	78	·9156	342·8323
79	·3808	330·8752	2	810·8752	·6192	79	79	·9077	359·7479
79	·3729	348·2560	3	768·2560	·6271	79	78	·8999	376·6556
79	·3650	365·6289	4	725·6289	·6350	79	79	·8920	393·5555
80	·3570	382·9939	55	682·9939	·6430	80	78	·8842	410·4475
78	·3492	400·3509	6	640·3509	·6508	78	79	·8763	427·3317
80	·3412	417·7001	7	597·7001	·6588	80	78	·8685	444·2080
79	·3333	435·0413	8	555·0413	·6667	79	79	·8606	461·0765
79	·3254	452·3746	9	512·3746	·6746	79	78	16·8528	477·9371
	17·3254	138469·7000	60	48469·7000	42·6746				139494·7899

′	−25°.	Diff.	Δ².	Δ².	Diff.	26°.	′	−26°.	Diff.	Δ².
	″	″			″	″		″	″	
0	48469·7000	42·6825	79	78	16·8450	139494·7899	0	45894·7899	43·1550	78
1	427·0175	·6904	79	79	·8371	511·6349	1	851·6349	·1629	79
2	384·3271	·6983	79	79	·8292	528·4720	2	808·4720	·1708	79
3	341·6288	·7062	79	78	·8214	545·3012	3	765·3012	·1786	78
4	298·9226	·7141	80	78	·8136	562·1226	4	722·1226	·1864	78
5	256·2085.	·7221	78	79	·8057	578·9362	5	678·9362	·1943	79
6	213·4864	·7299	79	77	·7980	595·7419	6	635·7419	·2020	77
7	170·7565.	·7378	80	79	·7901	612·5399	7	592·5399	·2099	79
8	128·0187	·7458	78	79	·7822	629·3300	8	549·3300	·2178	79
9	085·2729	·7536		78	·7744	646·1122	9	506·1122	·2256	78
10	48042·5193	·7615	79	79	·7665	662·8866	10	462·8866	·2335	79
1	47999·7578	·7695	80	77	·7588	679·6531	1	419·6531	·2412	77
2	956·9883	·7773	78	79	·7509	696·4119	2	376·4119	·2491	79
3	914·2110	·7852	79	78	·7431	713·1628	3	333·1628	·2569	78
4	871·4258	·7931	79	79	·7352	729·9059	4	289·9059	·2648	79
15	828·6327	·8010	79	78	·7274	746·6411	15	246·6411	·2726	78
6	785·8317	·8089	79	78	·7196	763·3685	6	203·3685	·2804	78
7	743·0228	·8168	79	78	·7118	780·0881	7	160·0881	·2882	78
8	700·2060	·8247	79	78	·7040	796·7999	8	116·7999	·2960	78
9	657·3813	·8326	79	79	·6961	813·5039	9	073·5039	·3039	79
20	614·5487	·8405	79	78	·6883	830·2000	20	45030·2000	·3117	78
1	571·7082	·8483	78	78	·6805	846·8883	1	44986·8883	·3195	78
2	528·8599	·8562	79	78	·6727	863·5688	2	943·5688	·3273	78
3	486·0037	·8641	79	79	·6648	880·2415	3	900·2415	·3352	79
4	443·1396	·8720	79	77	·6571	896·9063	4	856·9063	·3429	77
25	400·2676	·8799	79	79	·6492	913·5634	25	813·5634	·3508	79
6	357·3877	·8878	79	78	·6414	930·2126	6	770·2126	·3586	78
7	314·4999	·8956	78	78	·6336	946·8540	7	726·8540	·3664	78
8	271·6043	·9035	79	78	·6258	963·4876	8	683·4876	·3742	78
9	228·7008	·9114	79	78	·6180	980·1134	9	640·1134	·3820	78
30	185·7894	·9193	79	79	·6101	139996·7314	30	596·7314	·3899	79
1	142·8701	·9271	78	77	·6024	140013·3415	1	553·3415	·3976	77
2	099·9430	·9350	79	79	·5945	029·9439	2	509·9439	·4055	79
3	057·0080	·9429	79	78	·5867	046·5384	3	466·5384	·4133	78
4	47014·0651	·9508	79	77	·5790	063·1251	4	423·1251	·4210	77
35	46971·1143	·9586	78	79	·5711	079·7041	35	379·7041	·4289	79
6	928·1557	·9665	79	78	·5633	096·2752	6	336·2752	·4367	78
7	885·1892	·9744	79	78	·5555	112·8385	7	292·8385	·4445	78
8	842·2148	·9823	79	77	·5478	129·3940	8	249·3940	·4522	77
9	799·2325	·9901	78	79	·5399	145·9418	9	205·9418	·4601	79
40	756·2424	42·9980	79	78	·5321	162·4817	40	162·4817	·4679	78
1	713·2444	43·0058	78	77	·5244	179·0138	1	119·0138	·4756	77
2	670·2386	·0137	79	79	·5165	195·5382	2	075·5382	·4835	79
3	627·2249	·0216	79	78	·5087	212·0547	3	44032·0547	·4913	78
4	584·2033	·0294	78	77	·5010	228·5634	4	43988·5634	·4990	77
45	541·1739	·0373	79	79	·4931	245·0644	45	945·0644	·5069	79
6	498·1366	·0451	78	77	·4854	261·5575	6	901·5575	·5146	77
7	455·0915.	·0530	79	78	·4776	278·0429	7	858·0429	·5224	78
8	412·0385.	·0609	79	79	·4697	294·5205.	8	814·5205.	·5303	79
9	368·9776	·0687	78	77	·4620	310·9902	9	770·9902	·5380	77
50	325·9089	·0766	79	78	·4542	327·4522	50	727·4522	·5458	78
1	282·8323	·0844	78	78	·4464	343·9064	1	683·9064	·5536	78
2	239·7479	·0923	79	77	·4387	360·3528	2	640·3528	·5613	77
3	196·6556	·1001	78	79	·4308	376·7915.	3	596·7915.	·5692	79
4	153·5555.	·1080	79	77	·4231	393·2223	4	553·2223	·5769	77
55	110·4475.	·1158	78	78	·4153	409·6454	55	509·6454	·5847	78
6	067·3317	·1237	79	78	·4075	426·0607	6	466·0607	·5925	78
7	46024·2080	·1315	78	78	·3997	442·4682	7	422·4682	·6003	78
8	45981·0765.	·1394	79	77	·3920	458·8679	8	378·8679	·6080	77
9	937·9371		78	79	16·3841	475·2599	9	335·2599		79
60	45894·7899	43·1472				140491·6440	60	43291·6440	43·6159	

Δ^4.	Diff.	27°.	′	-27°.	Diff.	Δ^4.	Δ^4.	Diff.	28°.
	″	″		″	″			″	″
77	16·3764	140491·6440	0	43291·6440	43·6236	77	77	15·9120	141460·5071
77	·3687	508·0204	1	248·0204	·6313	77	77	·9043	476·4191
79	·3608	524·3891	2	204·3891	·6392	79	77	·8966	492·3231
77	·3531	540·7499	3	160·7499	·6469	77	77	·8889	508·2200
78	·3453	557·1030	4	117·1030	·6547	78	77	·8812	524·1089
78	·3375	573·4483	5	073·4483	·6625	78	77	·8735	539·9901
77	·3298	589·7858	6	43029·7858	·6702	77	77	·8658	555·8636
78	·3220	606·1156	7	42986·1156	·6780	78	78	·8580	571·7294
78	·3142	622·4376	8	942·4376	·6858	78	76	·8504	587·5874
77	·3065	638·7518	9	898·7518	·6935	77	77	·8427	603·4378
78	·2987	655·0583	10	855·0583	·7013	78	77	·8350	619·2805
77	·2910	671·3570	1	811·3570	·7090	77	76	·8274	635·1155
79	·2831	687·6480	2	767·6480	·7169	79	78	·8196	650·9429
77	·2754	703·9311	3	723·9311	·7246	77	77	·8119	666·7625
77	·2677	720·2065	4	680·2065	·7323	77	76	·8043	682·5744
78	·2599	736·4742	15	636·4742	·7401	78	77	·7966	698·3787
77	·2522	752·7341	6	592·7341	·7478	77	77	·7889	714·1753
78	·2444	768·9863	7	548·9863	·7556	78	77	·7812	729·9642
78	·2366	785·2307	8	505·2307	·7634	78	77	·7735	745·7454
77	·2289	801·4673	9	461·4673	·7711	77	77	·7658	761·5189
78	·2211	817·6962	20	417·6962	·7789	78	76	·7582	777·2847
77	·2134	833·9173	1	373·9173	·7866	77	78	·7504	793·0429
78	·2056	850·1307	2	330·1307	·7944	78	76	·7428	808·7933
77	·1979	866·3363	3	286·3363	·8021	77	77	·7351	824·5361
78	·1901	882·5342	4	242·5342	·8099	77	76	·7275	840·2712
77	·1824	898·7243	25	198·7243	·8176	78	77	·7197	855·9987
78	·1746	914·9067	6	154·9067	·8254	78	76	·7121	871·7184
77	·1669	931·0813	7	111·0813	·8331	77	77	·7044	887·4305
77	·1592	947·2482	8	067·2482	·8408	77	76	·6968	903·1349
78	·1514	963·4074	9	42023·4074	·8486	78	78	·6890	918·8317
77	·1437	979·5588	30	41979·5588	·8563	77	76	·6814	934·5207
78	·1359	140995·7025.	1	935·7025.	·8641	78	76	·6738	950·2021
77	·1282	141011·8384	2	891·8384	·8718	77	78	·6660	965·8759
77	·1205	027·9666	3	847·9666	·8795	77	76	·6584	981·5419
78	·1127	044·0871	4	804·0871	·8873	78	76	·6508	141997·2003
77	·1050	060·1998	35	760·1998	·8950	77	77	·6431	142012·8511
78	·0972	076·3048	6	716·3048	·9028	78	77	·6354	028·4942
76	·0896	092·4020	7	672·4020	·9104	76	77	·6277	044·1296
78	·0818	108·4916	8	628·4916	·9182	78	76	·6201	059·7573
78	·0740	124·5734	9	584·5734	·9260	78	77	·6124	075·3774
77	·0663	140·6474	40	540·6474	·9337	77	76	·6048	090·9898
77	·0586	156·7137	1	496·7137	·9414	77	76	·5972	106·5946
77	·0509	172·7723	2	452·7723	·9491	77	78	·5894	122·1918
77	·0432	188·8232	3	408·8232	·9568	77	76	·5818	137·7812
78	·0354	204·8664	4	364·8664	·9646	78	76	·5742	153·3630
77	·0277	220·9018	45	320·9018	·9723	77	77	·5665	168·9372
77	·0200	236·9295.	6	276·9295.	·9800	77	76	·5589	184·5037
78	·0122	252·9495.	7	232·9495.	·9878	78	77	·5512	200·0626
77	16·0045	268·9617	8	188·9617	43·9955	77	76	·5436	215·6138
76	15·9969	284·9662	9	144·9662	44·0031	76	77	·5359	231·1574
78	·9891	300·9631	50	100·9631	·0109	78	77	·5282	246·6933
77	·9814	316·9522	1	056·9522	·0186	77	76	·5206	262·2215
77	·9737	332·9336	2	41012·9336	·0263	77	76	·5130	277·7421
78	·9659	348·9073	3	40968·9073	·0341	78	76	·5054	293·2551
76	·9583	364·8732	4	924·8732	·0417	76	77	·4977	308·7605
78	·9505	380·8315.	55	880·8315.	·0495	78	76	·4901	324·2582
77	·9428	396·7820	6	836·7820	·0572	77	77	·4824	339·7483
77	·9351	412·7248	7	792·7248	·0649	77	76	·4748	355·2307
76	·9275	428·6599	8	748·6599	·0725	76	76	·4672	370·7055
78	15·9197	444·5874	9	704·5874	44·0803	78	77	15·4595	386·1727
		141460·5071	60	40660·5071					142401·6322

′	−28°.	Diff.	Δ².	Δ².	Diff.	29°.	′	−29°.	Diff.	Δ².
	″	″			″	″		″	″	
0	40660·5071	44·0880	77	76	15·4519	142401·6322	0	38001·6322	44·5481	76
1	616·4191	·0957	77	76	·4443	417·0841	1	37957·0841	·5557	76
2	572·3234	·1034	77	77	·4366	432·5284	2	912·5284	·5634	77
3	528·2200	·1111	77	76	·4290	447·9650	3	867·9650	·5710	76
4	484·1089	·1188	77	76	·4214	463·3940	4	823·3940	·5786	76
5	439·9901	·1265	77	77	·4137	478·8154	5	778·8154	·5863	77
6	395·8636	·1342	77	75	·4062	494·2291	6	734·2291	·5938	75
7	351·7294	·1420	78	77	·3985	509·6353	7	689·6353	·6015	77
8	307·5874	·1496	76	76	·3909	525·0338	8	645·0338	·6091	76
9	263·4378	·1573	77	77	·3832	540·4247	9	600·4247	·6168	77
10	219·2805	·1650	77	76	·3756	555·8079	10	555·8079	·6244	76
1	175·1155	·1726	76	75	·3681	571·1835	1	511·1835	·6319	75
2	130·9429	·1804	78	77	·3604	586·5516	2	466·5516	·6396	79
3	086·7625	·1881	77	76	·3528	601·9120	3	421·9120	·6472	76
4	40042·5744	·1957	76	77	·3451	617·2648	4	377·2648	·6549	77
15	39998·3787	·2034	77	75	·3376	632·6099	15	332·6099	·6624	75
6	954·1753	·2111	77	77	·3299	647·9475·	6	287·9475·	·6701	77
7	909·9642	·2188	77	75	·3224	663·2774	7	243·2774	·6776	75
8	865·7454	·2265	77	77	·3147	678·5998	8	198·5998	·6853	77
9	821·5189	·2342	77	76	·3071	693·9145·	9	153·9145·	·6929	76
20	777·2847	·2418	76	76	·2995	709·2216	20	109·2216	·7005	76
1	733·0429	·2496	78	76	·2919	724·5211	1	064·5211	·7081	76
2	688·7933	·2572	76	76	·2843	739·8130	2	37019·8130	·7157	76
3	644·5361	·2649	77	76	·2767	755·0973	3	36975·0973	·7233	76
4	600·2712	·2725	76	76	·2691	770·3740	4	930·3740	·7309	76
25	555·9987	·2803	78	77	·2614	785·6431	25	885·6431	·7386	77
6	511·7184	·2879	76	75	·2539	800·9045	6	840·9045	·7461	75
7	467·4305·	·2956	77	76	·2463	816·1584	7	796·1584	·7537	76
8	423·1349	·3032	76	76	·2387	831·4047	8	751·4047	·7613	76
9	378·8317	·3110	78	76	·2311	846·6434	9	706·6434	·7689	76
30	334·5207	·3186	76	76	·2235	861·8745	30	661·8745	·7765	76
1	290·2021	·3262	76	76	·2159	877·0980	1	617·0980	·7841	76
2	245·8759	·3340	78	76	·2083	892·3139	2	572·3139	·7917	76
3	201·5419	·3416	76	76	·2007	907·5222	3	527·5222	·7993	76
4	157·2003	·3492	76	76	·1931	922·7229	4	482·7229	·8069	76
35	112·8511	·3569	77	75	·1856	937·9160	35	437·9160	·8144	75
6	068·4942	·3646	77	77	·1779	953·1016	6	393·1016	·8221	77
7	39024·1296	·3723	77	75	·1704	968·2795	7	348·2795	·8296	75
8	38979·7573	·3799	76	76	·1628	983·4499	8	303·4499	·8372	76
9	935·3774	·3876	77	76	·1552	142998·6127	9	258·6127	·8448	76
40	890·9898	·3952	76	76	·1476	143013·7679	40	213·7679	·8524	76
1	846·5946	·4028	76	76	·1400	028·9155·	1	168·9155·	·8600	76
2	802·1918	·4106	78	75	·1325	044·0555	2	124·0555	·8675	75
3	757·7812	·4182	76	77	·1248	059·1880	3	079·1880	·8752	77
4	713·3630	·4258	76	75	·1173	074·3128	4	36034·3128	·8827	75
45	668·9372	·4335	77	76	·1097	089·4301	45	35989·4301	·8903	76
6	624·5037	·4411	76	75	·1022	104·5398	6	944·5398	·8978	75
7	580·0626	·4488	76	77	·0945	119·6420	7	899·6420	·9055	77
8	535·6138	·4564	76	75	·0870	134·7365	8	854·7365	·9130	75
9	491·1574	·4641	77	75	·0795	149·8235	9	809·8235	·9205	75
50	446·6933	·4718	77	77	·0718	164·9030	50	764·9030	·9282	77
1	402·2215	·4794	76	75	·0643	179·9748	1	719·9748	·9357	75
2	357·7421	·4870	76	76	·0567	195·0391	2	675·0391	·9433	76
3	313·2551	·4946	76	75	·0492	210·0958	3	630·0958	·9508	75
4	268·7605	·5023	77	76	·0416	225·1450·	4	585·1450·	·9584	76
55	224·2582	·5099	76	76	·0340	240·1866	55	540·1866	·9660	76
6	179·7485	·5176	77	76	·0264	255·2206	6	495·2206	·9736	76
7	135·2307	·5252	76	75	·0189	270·2470	7	450·2470	·9811	75
8	090·7055	·5328	76	75	·0114	285·2659	8	405·2659	·9886	75
9	046·1727	44·5405	77	76	15·0038	300·2773	9	360·2773	44·9962	76
60	38001·6322					143315·2811	60	35315·2811		

Δ².	Diff.	30°.	′	−30°.	Diff.	Δ².	Δ².	Diff.	31².
	″	″		″	″			″	″
76		143315·2811	0	35315·2811		76	75		144201·7236
76	14·9962	330·2773	1	270·2773	45·0038	76	75	14·5451	216·2687
75	·9886	345·2659	2	225·2659	·0114	75	74	·5376	230·8063
75	·9811	360·2470	3	180·2470	·0189	75	75	·5302	245·3365
76	·9736	375·2206	4	135·2206	·0264	76	75	·5227	259·8592
75	·9660	390·1866	5	090·1866	·0340	75	75	·5152	274·3744
76	·9585	405·1451	6	045·1451	·0415	76	74	·5077	288·8821
76	·9509	420·0960	7	35000·0960	·0491	76	75	·5003	303·3824
75	·9433	435·0393	8	34955·0393	·0567	75	75	·4928	317·8752
75	·9358	449·9751	9	909·9751	·0642	75	74	·4853	332·3605
	·9283				·0717			·4779	
76		464·9034	10	864·9034		76	75		346·8384
75	·9207	479·8241	1	819·8241	·0793	75	75	·4704	361·3088
76	·9132	494·7373	2	774·7373	·0868	76	74	·4629	375·7717
75	·9056	509·6429	3	729·6429	·0944	75	75	·4555	390·2272
75	·8981	524·5410	4	684·5410	·1019	75	75	·4480	404·6752
76	·8906	539·4316	15	639·4316	·1094	76	74	·4405	419·1157
76	·8830	554·3146	6	594·3146	·1170	76	75	·4331	433·5488
74	·8754	569·1900	7	549·1900	·1246	74	75	·4256	447·9744
76	·8680	584·0580	8	504·0580	·1320	76	74	·4181	462·3925
76	·8604	598·9184	9	458·9184	·1396	76	74	·4107	476·8032
	·8528				·1472			·4033	
74		613·7712	20	413·7712		74	75		491·2065
76	·8454	628·6166	1	368·6166	·1546	76	75	·3958	505·6023
75	·8378	643·4544	2	323·4544	·1622	75	74	·3883	519·9906
76	·8303	658·2847	3	278·2847	·1697	76	75	·3809	534·3715
75	·8227	673·1074	4	233·1074	·1773	75	74	·3734	548·7449
75	·8152	687·9226	25	187·9226	·1848	75	75	·3660	563·1109
75	·8077	702·7303	6	142·7303	·1923	75	74	·3585	577·4694
75	·8002	717·5305	7	097·5305	·1998	75	74	·3511	591·8205
76	·7927	732·3232	8	052·3232	·2073	76	75	·3437	606·1642
75	·7851	747·1083	9	34007·1083	·2149	75	74	·3362	620·5004
	·7776				·2224			·3288	
75		761·8859	30	33961·8859		75	75		634·8292
75	·7701	776·6560	1	916·6560	·2299	75	74	·3213	649·1505
76	·7626	791·4186	2	871·4186	·2374	76	75	·3139	663·4644
74	·7550	806·1736	3	826·1736	·2450	74	74	·3064	677·7708
76	·7476	820·9212	4	780·9212	·2524	76	74	·2990	692·0698
75	·7400	835·6612	35	735·6612	·2600	75	75	·2916	706·3614
75	·7325	850·3937	6	690·3937	·2675	75	74	·2841	720·6455
75	·7250	865·1187	7	645·1187	·2750	75	74	·2767	734·9222
75	·7175	879·8362	8	599·8362	·2825	75	75	·2693	749·1915
75	·7100	894·5462	9	554·5462	·2900	75	75	·2618	763·4533
	·7025				·2975		73	·2545	
76		909·2487	40	509·2487		76	76		777·7078
74	·6949	923·9436	1	463·9436	·3051	74	73	·2469	791·9547
75	·6875	938·6311	2	418·6311	·3125	75	75	·2396	806·1943
76	·6800	953·3111	3	373·3111	·3200	76	73	·2321	820·4264
74	·6724	967·9835	4	327·9835	·3276	74	75	·2248	834·6512
76	·6650	982·6485.	45	282·6485.	·3350	76	75	·2173	848·8685.
74	·6574	143997·3059	6	237·3059	·3426	76	73	·2098	863·0783
76	·6500	144011·9559	7	191·9559	·3500	74	75	·2025	877·2808
74	·6424	026·5983	8	146·5983	·3576	76	75	·1950	891·4758
75	·6350	041·2333	9	101·2333	·3650	74	74	·1876	905·6634
	·6275				·3725	75	73	·1803	
75		055·8608	50	055·8608		75	76		919·8437
75	·6200	070·4808	1	33010·4808	·3800	75	73	·1727	934·0164
75	·6125	085·0933	2	32965·0933	·3875	75	74	·1654	948·1818
75	·6050	099·6983	3	919·6983	·3950	75	75	·1580	962·3398
75	·5975	114·2958	4	874·2958	·4025	75	73	·1505	976·4903
75	·5900	128·8858	55	828·8858	·4100	75	75	·1432	144990·6335
75	·5825	143·4683	6	783·4683	·4175	75	74	·1357	145004·7692
74	·5751	158·0434	7	738·0434	·4249	74	73	·1283	018·8975
76	·5675	172·6109	8	692·6109	·4325	76	75	·1210	033·0185
74	·5601	187·1710	9	647·1710	·4399	74	74	·1135	047·1320
75	14·5526	144201·7236	60	32601·7236	45·4474	75	74	14·1061	145061·2381

′	−31°.	Diff.	Δ².	Δ².	Diff.	32°.	′	−32°.	Diff.	Δ².
	″	″			″	″		″	″	
0	32601·7236	45·4549	75	74	14·0987	145061·2381	0	29861·2381	45·9013	74
1	556·2687	·4624	75	73	·0914	075·3368	1	815·3368	·9086	73
2	510·8063	·4698	74	75	·0839	089·4282	2	769·4282	·9161	75
3	465·3365	·4773	75	74	·0765	103·5121	3	723·5121	·9235	74
4	419·8592	·4848	75	73	·0692	117·5886	4	677·5886	·9308	73
5	374·3744	·4923	75	75	·0617	131·6578	5	631·6578	·9383	75
6	328·8821	·4997	74	74	·0543	145·7195.	6	585·7195.	·9457	74
7	283·3824	·5072	75	73	·0470	159·7738	7	539·7738	·9530	73
8	237·8752	·5147	75	75	·0395	173·8208	8	493·8208	·9605	75
9	192·3605	·5221	74	73	·0322	187·8603	9	447·8603	·9678	73
10	146·8384	·5296	75	74	·0248	201·8925	10	401·8925	·9752	74
1	101·3088	·5371	75	74	·0174	215·9173	1	355·9173	·9826	74
2	055·7717	·5445	74	74	·0100	229·9347	2	309·9347	·9900	74
3	32010·2272	·5520	75	73	14·0027	243·9447	3	263·9447	45·9973	73
4	31964·6752	·5595	75	75	13·9952	257·9474	4	217·9474	46·0048	75
15	919·1157	·5669	74	73	·9879	271·9426	15	171·9426	·0121	73
6	873·5488	·5744	75	74	·9805	285·9305	6	125·9305	·0195	74
7	827·9744	·5819	75	74	·9731	299·9110	7	079·9110	·0269	74
8	782·3925	·5893	74	73	·9658	313·8841	8	29033·8841	·0342	73
9	736·8032	·5967	74	75	·9583	327·8499	9	28987·8499	·0417	75
20	691·2065.	·6042	75	73	·9510	341·8082	20	941·8082	·0490	73
1	645·6023	·6117	75	74	·9436	355·7592	1	895·7592	·0564	74
2	599·9906	·6191	74	73	·9363	369·7028	2	849·7028	·0637	73
3	554·3715.	·6266	75	74	·9289	383·6391	3	803·6391	·0711	74
4	508·7449	·6340	74	74	·9215	397·5680	4	757·5680	·0785	74
25	463·1109	·6415	75	74	·9141	411·4895.	25	711·4895.	·0859	74
6	417·4694	·6489	74	73	·9068	425·4036	6	665·4036	·0932	73
7	371·8205	·6563	74	74	·8994	439·3104	7	619·3104	·1006	74
8	326·1642	·6638	75	73	·8921	453·2098	8	573·2098	·1079	73
9	280·5004	·6712	74	74	·8847	467·1019	9	527·1019	·1153	74
30	234·8292	·6787	75	74	·8773	480·9866	30	480·9866	·1227	74
1	189·1505.	·6861	74	73	·8700	494·8639	1	434·8639	·1300	73
2	143·4644	·6936	75	74	·8626	508·7339	2	388·7339	·1374	74
3	097·7708	·7010	74	73	·8553	522·5965	3	342·5965	·1447	73
4	052·0698	·7084	74	74	·8479	536·4518	4	296·4518	·1521	74
35	31006·3614	·7159	75	74	·8405	550·2997	35	250·2997	·1595	74
6	30960·6455	·7233	74	73	·8332	564·1402	6	204·1402	·1668	73
7	914·9222	·7307	74	73	·8259	577·9734	7	157·9734	·1741	73
8	869·1915.	·7382	75	74	·8185	591·7993	8	111·7993	·1815	74
9	823·4533	·7455	73	74	·8111	605·6178	9	065·6178	·1889	74
40	777·7078	·7531	76	73	·8038	619·4289	40	28019·4289	·1962	73
1	731·9547	·7604	73	73	·7965	633·2327	1	27973·2327	·2035	73
2	686·1943	·7679	75	74	·7891	647·0292	2	927·0292	·2109	74
3	640·4264	·7752	73	73	·7818	660·8183	3	880·8183	·2182	73
4	594·6512	·7827	75	74	·7744	674·6001	4	834·6001	·2256	74
45	548·8685.	·7902	75	73	·7671	688·3745	45	788·3745	·2329	73
6	503·0783	·7975	73	73	·7598	702·1416	6	742·1416	·2402	73
7	457·2808	·8050	75	74	·7524	715·9014	7	695·9014	·2476	74
8	411·4758	·8124	74	73	·7451	729·6538	8	649·6538	·2549	74
9	365·6634	·8197	73	74	·7377	743·3989	9	603·3989	·2623	74
50	319·8437	·8273	76	73	·7304	757·1366	50	557·1366	·2696	73
1	274·0164	·8346	73	73	·7231	770·8670	1	510·8670	·2769	73
2	228·1818	·8420	74	73	·7158	784·5901	2	464·5901	·2842	73
3	182·3398	·8495	75	74	·7084	798·3059	3	418·3059	·2916	74
4	136·4903	·8568	73	73	·7011	812·0143	4	372·0143	·2989	73
55	090·6335.	·8643	75	73	·6938	825·7154	55	325·7154	·3062	73
6	30044·7692	·8717	74	73	·6865	839·4092	6	279·4092	·3135	73
7	29998·8975	·8790	73	74	·6791	853·0957	7	233·0957	·3209	74
8	953·0185.	·8865	75	73	·6718	866·7748	8	186·7748	·3282	73
9	907·1320		74	73		880·4466	9	140·4466		73
60	29861·2381	45·8939			13·6645	145894·1111	60	27094·1111	46·3355	

Δ².	Diff.	38°.	′	−33°.	Diff.	Δ².	Δ².	Diff.	34°.
	″	″		″	″			″	″
73		145894·1111	0	27094·1111		73	72		146700·6371
	13·6572				46·3428			13·2206	
74		907·7683	1	047·7683		74	72		713·8577
	·6498				·3502			·2134	
72		921·4181	2	27001·4181		72	73		727·0711
	·6426				·3574			·2061	
74		935·0607	3	26955·0607		74	72		740·2772
	·6352				·3648			·1989	
73		948·6959	4	908·6959		73	72		753·4761
	·6279				·3721			·1917	
73		962·3238	5	862·3238		73	73		766·6678
	·6206				·3794			·1844	
73		975·9444	6	815·9444		73	71		779·8522
	·6133				·3867			·1773	
74		145989·5577	7	769·5577		74	73		793·0295
	·6059				·3941			·1700	
72		146003·1636	8	723·1636		72	73		806·1995
	·5987				·4013			·1627	
73		016·7623	9	676·7623		73	71		819·3622
	·5914				·4086			·1556	
74		030·3537	10	630·3537		74	73		832·5178
	·5840				·4160			·1483	
72		043·9377	1	583·9377		72	72		845·6661
	·5768				·4232			·1411	
73		057·5145	2	537·5145		73	72		858·8072
	·5695				·4305			·1339	
74		071·0840	3	491·0840		74	72		871·9411
	·5621				·4379			·1267	
72		084·6461	4	444·6461		72	73		885·0678
	·5549				·4451			·1194	
74		098·2010	15	398·2010		74	71		898·1872
	·5475				·4525			·1123	
72		111·7485	6	351·7485		72	73		911·2995
	·5403				·4597			·1050	
74		125·2888	7	305·2888		74	72		924·4045
	·5329				·4671			·0978	
72		138·8217	8	258·8217		72	72		937·5023
	·5257				·4743			·0906	
73		152·3474	9	212·3474		73	72		950·5929
	·5184				·4816			·0834	
73		165·8658	20	165·8658		73	72		963·6763
	·5111				·4889			·0762	
73		179·3769	1	119·3769		73	72		976·7525
	·5038				·4962			·0690	
73		192·8807	2	072·8807		73	72		146989·8215
	·4965				·5035			·0618	
73		206·3772	3	26026·3772		73	72		147002·8833
	·4892				·5108			·0546	
73		219·8664	4	25979·8664		73	72		015·9379
	·4819				·5181			·0474	
72		233·3483	25	933·3483		72	72		028·9853
	·4747				·5253			·0402	
74		246·8230	6	886·8230		74	72		042·0255
	·4673				·5327			·0330	
72		260·2903	7	840·2903		72	72		055·0585
	·4601				·5399			·0258	
73		273·7504	8	793·7504		73	72		068·0843
	·4528				·5472			·0186	
72		287·2032	9	747·2032		72	72		081·1029
	·4456				·5544			·0114	
74		300·6488	30	700·6488		74	72		094·1143
	·4382				·5618			13·0042	
72		314·0870	1	654·0870		72	71		107·1185
	·4310				·5690			12·9971	
73		327·5180	2	607·5180		73	73		120·1156
	·4237				·5763			·9898	
73		340·9417	3	560·9417		73	72		133·1054
	·4164				·5836			·9826	
72		354·3581	4	514·3581		72	71		146·0880
	·4092				·5908			·9755	
73		367·7673	35	467·7673		73	72		159·0635
	·4019				·5981			·9683	
73		381·1692	6	421·1692		73	72		172·0318
	·3946				·6054			·9611	
73		394·5638	7	374·5638		73	72		184·9929
	·3873				·6127			·9539	
72		407·9511	8	327·9511		72	72		197·9468
	·3801				·6199			·9467	
73		421·3312	9	281·3312		73	71		210·8935
	·3728				·6272			·9396	
72		434·7040	40	234·7040		72	72		223·8331
	·3656				·6344			·9324	
73		448·0696	1	188·0696		73	72		236·7655
	·3583				·6417			·9252	
73		461·4279	2	141·4279		73	72		249·6907
	·3510				·6490			·9180	
72		474·7789	3	094·7789		72	72		262·6087
	·3438				·6562			·9108	
73		488·1227	4	048·1227		73	71		275·5195
	·3365				·6635			·9037	
72		501·4592	45	25001·4592		72	72		288·4232
	·3293				·6707			·8965	
73		514·7885	6	24954·7885		73	71		301·3197
	·3220				·6780			·8894	
72		528·1105	7	908·1105		72	72		314·2091
	·3148				·6852			·8822	
73		541·4253	8	861·4253		73	72		327·0913
	·3075				·6925			·8750	
73		554·7328	9	814·7328		73	72		339·9663
	·3002				·6998			·8678	
72		568·0330	50	768·0330		72	71		352·8341
	·2930				·7070			·8607	
72		581·3260	1	721·3260		72	72		365·6948
	·2858				·7142			·8535	
73		594·6118	2	674·6118		73	71		378·5483
	·2785				·7215			·8464	
72		607·8903	3	627·8903		72	72		391·3947
	·2713				·7287			·8392	
73		621·1616	4	581·1616		73	72		404·2339
	·2640				·7360			·8320	
72		634·4256	55	534·4256		72	71		417·0659
	·2568				·7432			·8249	
73		647·6824	6	487·6824		73	72		429·8908
	·2495				·7505			·8177	
72		660·9319	7	440·9319		72	72		442·7085
	·2423				·7577			·8105	
72		674·1742	8	394·1742		72	70		455·5190
	·2351				·7649			·8035	
73		687·4093	9	347·4093		73	72		468·3225
	13·2278				46·7722			12·7963	
		146700·6371	60	24300·6371					147481·1188

′	−34°.	Diff.	Δ².	Δ².	Diff.	35°.	′	−35°.	Diff.	Δ².
	″	″			″	″		″	″	
0	24300·6371					147481·1188	0	21481·1188		
		46·7794	72	71	12·7892				47·2108	71
1	253·8577			72		493·9080	1	433·9080		
		·7866	72		·7820				·2180	72
2	207·0711			72		506·6900	2	386·6900		
		·7939	73		·7748				·2252	72
3	160·2772			71		519·4648	3	339·4648		
		·8011	72		·7677				·2323	71
4	113·4761			71		532·2325	4	292·2325		
		·8083	72		·7606				·2394	71
5	066·6678			72		544·9931	5	244·9931		
		·8156	73		·7534				·2466	72
6	24019·8522			71		557·7465.	6	197·7465.		
		·8227	71		·7463				·2537	71
7	23973·0295.			72		570·4928	7	150·4928		
		·8300	73		·7391				·2609	72
8	926·1995.			71		583·2319	8	103·2319		
		·8373	73		·7320				·2680	71
9	879·3622			71		595·9639	9	055·9639		
		·8444	71		·7249				·2751	71
10	832·5178					608·6888	10	21008·6888		
		·8517	73	72	·7177				·2823	72
1	785·6661			71		621·4065.	1	20961·4065.		
		·8589	72		·7106				·2894	71
2	738·8072			72		634·1171	2	914·1171		
		·8661	72		·7034				·2966	72
3	691·9411			70		646·8205	3	866·8205		
		·8733	72		·6964				·3036	70
4	645·0678			72		659·5169	4	819·5169		
		·8806	73		·6892				·3108	72
15	598·1872			72		672·2061	15	772·2061		
		·8877	71		·6820				·3180	72
6	551·2995.			70		684·8881	6	724·8881		
		·8950	73		·6750				·3250	70
7	504·4045			72		697·5631	7	677·5631		
		·9022	72		·6678				·3322	72
8	457·5023			71		710·2309	8	630·2309		
		·9094	72		·6607				·3393	71
9	410·5929			71		722·8916	9	582·8916		
		·9166	72		·6536				·3464	71
20	363·6763					735·5452	20	535·5452		
		·9238	72	71	·6465				·3535	71
1	316·7525			71		748·1917	1	488·1917		
		·9310	72		·6394				·3606	71
2	269·8215			72		760·8311	2	440·8311		
		·9382	72		·6322				·3678	72
3	222·8833			71		773·4633	3	393·4633		
		·9454	72		·6251				·3749	71
4	175·9379			71		786·0884	4	346·0884		
		·9526	72		·6180				·3820	71
25	128·9853			71		798·7064	25	298·7064		
		·9598	72		·6109				·3891	71
6	082·0255			71		811·3173	6	251·3173		
		·9670	72		·6038				·3962	71
7	23035·0585.			71		823·9211	7	203·9211		
		·9742	72		·5967				·4033	72
8	22988·0843			72		836·5178	8	156·5178		
		·9814	72		·5895				·4105	72
9	941·1029			70		849·1073	9	109·1073		
		·9886	72		·5825				·4175	70
30	894·1143					861·6898	30	061·6898		
		46·9958	72	71	·5754				·4246	71
1	847·1185			72		874·2652	1	20014·2652		
		47·0029	71		·5682				·4318	72
2	800·1156			73		886·8334	2	19966·8334		
		·0102	73	70	·5612				·4388	70
3	753·1054			72		899·3946	3	919·3946		
		·0174	72	72	·5540				·4460	72
4	706·0880			71		911·9486	4	871·9486		
		·0245	71	70	·5470				·4530	70
35	659·0635			72		924·4956	35	824·4956		
		·0317	72	71	·5399				·4601	71
6	612·0318			72		937·0355.	6	777·0355.		
		·0389	72	70	·5327				·4673	72
7	564·9929			71		949·5682	7	729·5682		
		·0461	72	72	·5257				·4743	70
8	517·9468			71		962·0939	8	682·0939		
		·0533	72	72	·5186				·4814	71
9	470·8935				·5114	974·6125	9	634·6125		
		·0604	71						·4886	72
40	423·8331					987·1239	40	587·1239		
		·0676	72	70	·5044				·4956	70
1	376·7655.			70		147999·6283	1	539·6283		
		·0748	72	72	·4974				·5026	70
2	329·6907				·4902	148012·1257	2	492·1257		
		·0820	72	70					·5098	72
3	282·6087				·4832	024·6159	3	444·6159		
		·0892	72	72					·5168	70
4	235·5195				·4760	037·0991	4	397·0991		
		·0963	71	71					·5240	72
45	188·4232				·4689	049·5751	45	349·5751		
		·1035	72	70					·5311	71
6	141·3197				·4619	062·0440	6	302·0440		
		·1106	71	71					·5381	70
7	094·2091				·4548	074·5059	7	254·5059		
		·1178	72	70					·5452	71
8	22047·0913				·4478	086·9607	8	206·9607		
		·1250	72	72					·5522	70
9	21999·9663				·4406	099·4085.	9	159·4085.		
		·1322	72						·5594	72
50	952·8341					111·8491	50	111·8491		
		·1393	71	70	·4336				·5664	70
1	905·6948			71		124·2827	1	064·2827		
		·1465	72	71	·4265				·5735	71
2	858·5483			71		136·7092	2	19016·7092		
		·1536	71		·4194				·5806	71
3	811·3947			70		149·1286	3	18969·1286		
		·1608	72	71	·4124				·5876	70
4	764·2339			71		161·5410	4	921·5410		
		·1680	72	71	·4053				·5947	71
55	717·0659			70		173·9463	55	873·9463		
		·1751	71		·3982				·6018	71
6	669·8908			70		186·3445	6	826·3445		
		·1823	72		·3912				·6088	70
7	622·7085			71		198·7357	7	778·7357		
		·1895	72		·3841				·6159	71
8	575·5190			71		211·1198	8	731·1198		
		·1965	70		·3770				·6230	71
9	528·3225			70		223·4968	9	683·4968		
		47·2037	72		12·3700				47·6300	70
60	21181·1188					148235·8668	60	18635·8668		

Δ°.	Diff.	36°.	′	−36°.	Diff.	Δ°.
	″	″		″		
71		148235·8668	0	18635·8668	47·6371	71
71	12·3629	248·2297	1	588·2297	·6442	71
70	·3558	260·5855	2	540·5855	·6512	70
70	·3488	272·9343	3	492·9343	·6582	70
71	·3418	285·2761	4	445·2761	·6653	71
71	·3347	297·6108	5	397·6108	·6724	71
70	·3276	309·9384	6	349·9384	·6794	70
71	·3206	322·2590	7	302·2590	·6865	71
70	·3135	334·5725	8	254·5725	·6935	70
70	·3065	346·8790	9	206·8790	·7005	70
71	·2995	359·1785.	10	159·1785.	·7076	71
71	·2924	371·4709	1	111·4709	·7147	71
70	·2853	383·7562	2	063·7562	·7217	70
70	·2783	396·0345	3	18016·0345	·7287	70
71	·2713	408·3058	4	17968·3058	·7358	71
70	·2642	420·5700	15	920·5700	·7428	70
70	·2572	432·8272	6	872·8272	·7498	70
71	·2502	445·0774	7	825·0774	·7569	71
70	·2431	457·3205.	8	777·3205.	·7639	70
71	·2361	469·5566	9	729·5566	·7710	71
69	·2290	481·7856	20	681·7856	·7779	69
71	·2221	494·0077	1	634·0077	·7850	71
71	·2150	506·2227	2	586·2227	·7921	71
69	·2079	518·4306	3	538·4306	·7990	69
71	·2010	530·6316	4	490·6316	·8061	71
70	·1939	542·8255.	25	442·8255.	·8131	70
70	·1869	555·0124	6	395·0124	·8201	70
71	·1799	567·1923	7	347·1923	·8272	71
69	·1728	579·3651	8	299·3651	·8341	69
71	·1659	591·5310	9	251·5310	·8412	71
70	·1588	603·6898	30	203·6898	·8482	70
70	·1518	615·8416	1	155·8416	·8552	70
70	·1448	627·9864	2	107·9864	·8622	70
70	·1378	640·1242	3	060·1242	·8692	70
71	·1308	652·2550.	4	17012·2550.	·8763	71
69	·1237	664·3787	35	16964·3787	·8832	69
71	·1168	676·4955.	6	916·4955.	·8903	71
69	·1097	688·6052	7	868·6052	·8972	69
71	·1028	700·7080	8	820·7080	·9043	71
69	·0957	712·8037	9	772·8037	·9112	69
71	·0888	724·8925.	40	724·8925.	·9183	71
69	·0817	736·9742	1	676·9742	·9252	69
71	·0748	749·0490	2	629·0490	·9323	71
69	·0677	761·1167	3	581·1167	·9392	69
71	·0608	773·1775.	4	533·1775.	·9463	71
69	·0537	785·2312	45	485·2312	·9532	69
70	·0468	797·2780	6	437·2780	·9602	70
71	·0398	809·3178	7	389·3178	·9673	71
69	·0327	821·3505	8	341·3505	·9742	69
70	·0258	833·3763	9	293·3763	·9812	70
69	·0188	845·3951	50	245·3951	·9881	69
71	·0119	857·4070	1	197·4070	47·9952	71
69	12·0048	869·4118	2	149·4118	48·0021	69
70	11·9979	881·4097	3	101·4097	·0091	70
70	·9909	893·4006	4	053·4006	·0161	70
70	·9839	905·3845.	55	16005·3845.	·0231	70
69	·9769	917·3614	6	15957·3614	·0300	69
71	·9700	929·3314	7	909·3314	·0371	71
69	·9629	941·2943	8	861·2943	·0440	69
69	·9560	953·2503	9	813·2503	48·0509	69
	11·9491	148965·1994	60	15765·1994		

Δ°.	Diff.	37°.
	″	″
71		148965·1994
69	11·9420	977·1414
69	·9351	148989·0765
71	·9282	149001·0047
69	·9211	012·9258
69	·9142	024·8400
70	·9073	036·7473
70	·9003	048·6476
70	·8933	060·5409
69	·8863	072·4272
69	·8794	084·3066
70	·8725	096·1791
70	·8655	108·0446
69	·8585	119·9031
70	·8516	131·7547
70	·8447	143·5994
69	·8377	155·4371
70	·8308	167·2679
69	·8238	179·0917
70	·8169	190·9086
69	·8099	202·7185
69	·8030	214·5215
70	·7961	226·3176
69	·7891	238·1067
70	·7822	249·8889
68	·7752	261·6641
70	·7684	273·4325
70	·7614	285·1939
68	·7544	296·9483
70	·7476	308·6959
69	·7406	320·4365
69	·7337	332·1702
70	·7268	343·8970
68	·7198	355·6168
70	·7130	367·3298
69	·7060	379·0358
69	·6991	390·7349
69	·6922	402·4271
70	·6853	414·1124
68	·6783	425·7907
70	·6715	437·4622
68	·6645	449·1267
70	·6577	460·7844
69	·6507	472·4351
68	·6438	484·0789
70	·6370	495·7159
69	·6300	507·3459
68	·6231	518·9690
70	·6163	530·5853
69	·6093	542·1946
68	·6024	553·7970
69	·5956	565·3926
69	·5887	576·9813
70	·5818	588·5631
68	·5748	600·1379
68	·5680	611·7059
70	·5612	623·2671
69	·5542	634·8213
68	·5473	646·3686
69	·5405	657·9091
	11·5336	149669·4427

′	−37°.	Diff.	Δ².	Δ².	Diff.	38°.	′	−38°.	Diff.	Δ².
	″	″			″	″		″	″	
0	15765·1994	48·0580	71	69	11·5267	149669·4427	0	12869·4427	48·4733	69
1	717·1414	·0649	69	68	·5199	680·9694	1	820·9694	·4801	68
2	669·0765	·0718	69	70	·5129	692·4893	2	772·4893	·4871	70
3	621·0047	·0789	71	68	·5061	704·0022	3	724·0022	·4939	68
4	572·9258	·0858	69	68	·4993	715·5083	4	675·5083	·5007	68
5	524·8400	·0927	69	70	·4923	727·0076	5	627·0076	·5077	70
6	476·7473	·0997	70	68	·4855	738·4999	6	578·4999	·5145	68
7	428·6476	·1067	70	69	·4786	749·9854	7	529·9854	·5214	69
8	380·5409	·1137	70	68	·4718	761·4640	8	481·4640	·5282	68
9	332·4272	·1206	69	69	·4649	772·9358	9	432·9358	·5351	69
10	284·3066	·1275	69	69	·4580	784·4007	10	384·4007	·5420	69
1	236·1791	·1345	70	68	·4512	795·8587	1	335·8587	·5488	68
2	188·0446	·1415	70	69	·4443	807·3099	2	287·3099	·5557	69
3	139·9031	·1484	69	68	·4375	818·7542	3	238·7542	·5625	68
4	091·7547	·1553	69	69	·4306	830·1917	4	190·1917	·5694	69
15	15043·5994	·1623	70	68	·4238	841·6223	15	141·6223	·5762	68
6	14995·4371	·1692	69	69	·4169	853·0461	6	093·0461	·5831	69
7	947·2679	·1762	70	69	·4100	864·4630	7	12044·4630	·5900	69
8	899·0917	·1831	69	68	·4032	875·8730	8	11995·8730	·5968	68
9	850·9086	·1901	70	68	·3964	887·2762	9	947·2762	·6036	68
20	802·7185	·1970	69	69	·3895	898·6726	20	898·6726	·6105	69
1	754·5215	·2039	69	68	·3827	910·0621	1	850·0621	·6173	68
2	706·3176	·2109	70	69	·3758	921·4448	2	801·4448	·6242	69
3	658·1067	·2178	69	68	·3690	932·8206	3	752·8206	·6310	68
4	609·8889	·2248	70	69	·3621	944·1896	4	704·1896	·6379	69
25	561·6641	·2316	68	68	·3553	955·5517	25	655·5517	·6447	68
6	513·4325	·2386	70	68	·3485	966·9070	6	606·9070	·6515	68
7	465·1939	·2456	70	69	·3416	978·2555	7	558·2555	·6584	69
8	416·9483	·2524	68	68	·3348	149989·5971	8	509·5971	·6652	68
9	368·6959	·2594	70	68	·3280	150000·9319	9	460·9319	·6720	68
30	320·4365	·2663	69	68	·3212	012·2599	30	412·2599	·6788	68
1	272·1702	·2732	69	69	·3143	023·5811	1	363·5811	·6857	69
2	223·8970	·2802	70	68	·3075	034·8954	2	314·8954	·6925	68
3	175·6168	·2870	68	69	·3006	046·2029	3	266·2029	·6994	69
4	127·3298	·2940	70	67	·2939	057·5035	4	217·5035	·7061	67
35	079·0358	·3009	69	69	·2870	068·7974	35	168·7974	·7130	69
6	14030·7349	·3078	69	68	·2802	080·0844	6	120·0844	·7198	68
7	13982·4271	·3147	69	68	·2734	091·3646	7	071·3646	·7266	68
8	934·1124	·3217	70	69	·2665	102·6380	8	11022·6380	·7335	69
9	885·7907	·3285	68	67	·2598	113·9045	9	10973·9045	·7402	67
40	837·4622	·3355	70	68	·2530	125·1643	40	925·1643	·7470	68
1	789·1267	·3423	68	69	·2461	136·4173	1	876·4173	·7539	69
2	740·7844	·3493	70	68	·2393	147·6634	2	827·6634	·7607	68
3	692·4351	·3562	69	68	·2325	158·9027	3	778·9027	·7675	68
4	644·0789	·3630	68	68	·2257	170·1352	4	730·1352	·7743	68
45	595·7159	·3700	70	68	·2189	181·3609	45	681·3609	·7811	68
6	547·3459	·3769	69	68	·2121	192·5798	6	632·5798	·7879	68
7	498·9690	·3837	68	68	·2053	203·7919	7	583·7919	·7947	68
8	450·5853	·3907	70	68	·1985	214·9972	8	534·9972	·8015	68
9	402·1946	·3976	69	69	·1916	226·1957	9	486·1957	·8084	69
50	353·7970	·4044	68	67	·1849	237·3873	50	437·3873	·8151	67
1	305·3926	·4113	69	68	·1781	248·5722	1	388·5722	·8219	68
2	256·9813	·4182	69	68	·1713	259·7503	2	339·7503	·8287	68
3	208·5631	·4252	70	68	·1645	270·9216	3	290·9216	·8355	68
4	160·1379	·4320	68	68	·1577	282·0861	4	242·0861	·8423	68
55	111·7059	·4388	68	67	·1510	293·2438	55	193·2438	·8490	67
6	063·2671	·4458	70	69	·1441	304·3948	6	144·3948	·8559	69
7	13014·8213	·4527	69	68	·1373	315·5389	7	095·5389	·8627	68
8	12966·3686	·4595	68	67	·1306	326·6762	8	10046·6762	·8694	67
9	917·9091	48·4664	69	68	11·1238	337·8068	9	9997·8068	48·8762	68
60	12869·4427					150348·9306	60	9948·9306		

Δ².	Diff.	39°.	′	−39°.	Diff.	Δ².	Δ².	Diff.	40°.
	″	″		″	″			″	″
68		150346·9306	0	9948·9306		68	67		151004·0043
68	11·1170	360·0476	1	900·0476	48·8830	68	66	10·7130	014·7173
68	·1102	371·1578	2	851·1578	·8808	68	68	·7064	025·4237
67	·1034	382·2612	3	802·2612	·8966	67	66	·6996	036·1233
68	·0967	393·3579	4	753·3579	·9033	68	66	·6930	046·8163
68	·0899	404·4478	5	704·4478	·9101	68	68	·6864	057·5027
68	·0831	415·5309	6	655·5309	·9169	68	67	·6796	068·1823
67	·0763	426·6072	7	606·6072	·9237	67	66	·6729	078·8552
68	·0696	437·6768	8	557·6768	·9304	68	67	·6663	089·5215
68	·0628	448·7396	9	508·7396	·9372	68	67	·6596	100·1811
	·0560				·9440			·6529	
67		459·7956	10	459·7956		67	66		110·8340
68	·0493	470·8449	1	410·8449	·9507	68	67	·6463	121·4803
68	·0425	481·8874	2	361·8874	·9575	68	66	·6396	132·1199
67	·0357	492·9231	3	312·9231	·9643	67	67	·6330	142·7529
68	·0290	503·9521	4	263·9521	·9710	68	67	·6263	153·3792
67	·0222	514·9743	15	214·9743	·9778	67	67	·6196	163·9988
68	·0155	525·9898	6	165·9898	·9845	68	67	·6129	174·6117
67	·0087	536·9985	7	116·9985	·9913	67	66	·6063	185·2180
68	11·0020	548·0005	8	068·0005	48·9980	68	67	·5996	195·8176
68	10·9952	558·9957	9	9018·9957	49·0048	68	66	·5930	206·4106
	·9884				·0116		67	·5863	
67		569·9841	20	8969·9841		67	66		216·9969
67	·9817	580·9658	1	920·9658	·0183	67	67	·5797	227·5766
68	·9750	591·9408	2	871·9408	·0250	68	66	·5730	238·1496
68	·9682	602·9090	3	822·9090	·0318	68	67	·5664	248·7160
67	·9614	613·8704	4	773·8704	·0386	67	66	·5597	259·2757
67	·9547	624·8251	25	724·8251	·0453	67	67	·5531	269·8288
68	·9480	635·7731	6	675·7731	·0520	68	66	·5464	280·3752
67	·9412	646·7143	7	626·7143	·0588	67	66	·5398	290·9150
67	·9345	657·6488	8	577·6488	·0655	67	67	·5332	301·4482
68	·9278	668·5766	9	528·5766	·0722	68	66	·5265	311·9747
	·9210				·0790			·5199	
67		679·4976	30	479·4976		67	67		322·4946
68	·9143	690·4119	1	430·4119	·0857	68	66	·5132	333·0078
66	·9075	701·3194	2	381·3194	·0925	66	66	·5066	343·5144
68	·9009	712·2203	3	332·2203	·0991	68	66	·5000	354·0144
68	·8941	723·1144	4	283·1144	·1059	68	67	·4934	364·5078
66	·8873	734·0017	35	234·0017	·1127	66	66	·4867	374·9945
68	·8807	744·8824	6	184·8824	·1193	68	67	·4801	385·4746
67	·8739	755·7563	7	135·7563	·1261	67	66	·4734	395·9480
68	·8672	766·6235	8	086·6235	·1328	68	65	·4668	406·4148
66	·8604	777·4839	9	8037·4839	·1396	66	67	·4603	416·8751
	·8538				·1462			·4536	
68		788·3377	40	7988·3377		68	67		427·3287
67	·8470	799·1847	1	939·1847	·1530	67	65	·4469	437·7756
66	·8403	810·0250	2	890·0250	·1597	66	67	·4404	448·2160
68	·8337	820·8587	3	840·8587	·1663	68	66	·4337	458·6497
68	·8269	831·6856	4	791·6856	·1731	68	65	·4271	469·0768
66	·8201	842·5057	45	742·5057	·1799	66	67	·4206	479·4974
67	·8135	853·3192	6	693·3192	·1865	67	67	·4139	489·9113
67	·8068	864·1260	7	644·1260	·1932	67	65	·4072	500·3185
68	·8001	874·9261	8	594·9261	·1999	68	66	·4007	510·7192
67	·7933	885·7194	9	545·7194	·2067	67	66	·3941	521·1133
	·7866				·2134			·3875	
66		896·5060	50	496·5060		66	66		531·5008
67	·7800	907·2860	1	447·2860	·2200	67	67	·3809	541·8817
68	·7733	918·0593	2	398·0593	·2267	68	65	·3742	552·2559
66	·7665	928·8258	3	348·8258	·2335	66	66	·3677	562·6236
67	·7599	939·5857	4	299·5857	·2401	67	67	·3611	572·9847
68	·7532	950·3389	55	250·3389	·2468	68	65	·3544	583·3391
66	·7464	961·0853	6	201·0853	·2536	66	66	·3479	593·6870
67	·7398	971·8251	7	151·8251	·2602	67	66	·3413	604·0283
67	·7331	982·5582	8	102·5582	·2669	67	65	·3347	614·3630
67	·7264	150993·2846	9	053·2846	·2736	67	67	·3282	624·6912
	10·7197	151004·0043	60	7004·0043	49·2803			10·3215	151635·0127

	−40°.	Diff.	Δ².	Δ².	Diff.	41°.	′	−41°.	Diff.	Δ².
	″	″			″	″		″	″	
	7004·0043	49·2870	67	66	10·3149	151635·0127	0	4035·0127	49·6851	66
	6954·7173	·2936	66	66	·3083	645·3276	1	3985·3276	·6917	66
	905·4237	·3004	68	65	·3018	655·6359	2	935·6359	·6982	65
	856·1233	·3070	66	66	·2952	665·9377	3	885·9377	·7048	66
	806·8163	·3136	66	66	·2886	676·2329	4	836·2329	·7114	66
	757·5027	·3204	68	66	·2820	686·5215	5	786·5215	·7180	66
	708·1823	·3271	67	65	·2755	696·8035	6	736·8035	·7245	65
	658·8552	·3337	66	66	·2689	707·0790	7	687·0790	·7311	66
	609·5215.	·3404	67	66	·2623	717·3479	8	637·3479	·7377	66
	560·1811	·3471	67	66	·2557	727·6102	9	587·6102	·7443	
	510·8340	·3537	66	65	·2492	737·8659	10	537·8659	·7508	65
	461·4803	·3604	67	66	·2426	748·1151	1	488·1151	·7574	66
	412·1199	·3670	66	66	·2360	758·3577	2	438·3577	·7640	66
	362·7529	·3737	67	65	·2295	768·5937	3	388·5937	·7705	65
	313·3792	·3804	67	66	·2229	778·8232	4	338·8232	·7771	66
	263·9988	·3871	67	66	·2163	789·0461	15	289·0461	·7837	66
	214·6117	·3937	66	65	·2098	799·2624	6	239·2624	·7902	65
	165·2180	·4004	67	65	·2033	809·4722	7	189·4722	·7967	65
	115·8176	·4070	66	66	·1967	819·6755.	8	139·6755.	·8033	66
	066·4106	·4137	67	66	·1901	829·8722	9	089·8722	·8099	66
	6016·9969	·4203	66	66	·1835	840·0623	20	3040·0623	·8165	66
	5967·5766	·4270	67	65	·1770	850·2458	1	2990·2458	·8230	65
	918·1496	·4336	66	65	·1705	860·4228	2	940·4228	·8295	65
	868·7160	·4403	67	66	·1639	870 5933	3	890·5933	·8361	66
	819·2757	·4469	66	65	·1574	880·7572	4	840·7572	·8426	65
	769·8288	·4536	67	66	·1508	890·9146	25	790·9146	·8492	66
	720·3752	·4602	66	65	·1443	901·0654	6	741·0654	·8557	65
	670·9150	·4668	66	66	·1377	911·2097	7	691·2097	·8623	66
	621·4482	·4735	67	65	·1312	921·3474	8	641·3474	·8688	65
	571·9747	·4801	66	65	·1247	931·4786	9	591·4786	·8753	65
	522·4946	·4868	67	65	·1182	941·6033	30	541·6033	·8818	65
	473·0078	·4934	66	66	·1116	951·7215.	1	491·7215.	·8884	66
	423·5144	·5000	66	66	·1050	961·8331	2	441·8331	·8950	66
	374·0144	·5066	66	65	·0985	971·9381	3	391·9381	·9015	65
	324·5078	·5133	67	65	·0920	982·0366	4	342·0366	·9080	65
	274·9945.	·5199	66	65	·0855	151992·1286	35	292·1286	·9145	65
	225·4746	·5266	67	65	·0790	152002·2141	6	242·2141	·9210	65
	175·9480	·5332	66	66	·0724	012·2931	7	192·2931	·9276	66
	126·4148	·5397	65	65	·0659	022·3655	8	142·3655	·9341	65
	076·8751	·5464	67	65	·0594	032·4314	9	092·4314	·9406	65
	5027·3287	·5531	67	65	·0529	042·4908	40	2042·4908	·9471	65
	4977·7756	·5596	65	66	·0463	052·5437	1	1992·5437	·9537	66
	928·2160	·5663	67	65	·0398	062·5900	2	942·5900	·9602	65
	878·6497	·5729	66	65	·0333	072·6298	3	892·6298	·9667	65
	829·0768	·5794	65	65	·0268	082·6631	4	842·6631	·9732	65
	779·4974	·5861	67	65	·0203	092·6899	45	792·6899	·9797	65
	729·9113	·5928	67	65	·0138	102·7102	6	742·7102	·9862	65
	680·3185	·5993	65	65	·0073	112·7240	7	692·7240	·9927	65
	630·7192	·6059	66	65	10·0008	122·7313	8	642·7313	49·9992	65
	581·1133	·6125	66	65	9·9943	132·7321	9	592·7321	50·0057	
	531·5008	·6191	66	66	·9877	142·7264	50	542·7264	·0123	66
	481·8817	·6258	67	64	·9813	152·7141	1	492·7141	·0187	64
	432·2559	·6323	65	65	·9748	162·6954	2	442·6954	·0252	65
	382·6236	·6389	66	66	·9682	172·6702	3	392·6702	·0318	66
	332·9847	·6456	67	64	·9618	182·6384	4	342·6384	·0382	64
	283·3391	·6521	65	65	·9553	192·6002	55	292·6002	·0447	65
	233·6870	·6587	66	65	·9488	202·5555.	6	242·5555.	·0512	65
	184·0283	·6653	66	65	·9423	212·5043	7	192·5043	·0577	65
	134·3630	·6718	65	65	·9358	222·4466	8	142·4466	·0642	65
	084·6912	·6785	67	65	9·9293	232·3824	9	092·3824	50·0707	
	4035·0127	49·6785				152242·3117	60	1042·3117		

Δ'	Diff.	42°.	′	−42°.	Diff.	Δ'	Δ'	Diff.	43°.
	"	"		"	"			"	"
64		152242·3117	0	1042·3117		64	65		152826·2648
66	9·9229	252·2346	1	992·2346	50·0771	66	63	9·5368	835·8016
64	·9163	262·1509	2	942·1509	·0837	64	64	·5305	845·3321
65	·9099	272·0608	3	892·0608	·0901	65	64	·5241	854·8562
65	·9034	281·9642	4	841·9642	·0966	65	63	·5177	864·3739
65	·8969	291·8611	5	791·8611	·1031	65	64	·5114	873·8853
64	·8904	301·7515	6	741·7515	·1096	64	64	·5050	883·3903
65	·8840	311·6355	7	691·6355	·1160	65	64	·4986	892·8889
65	·8775	321·5130	8	641·5130	·1225	65	63	·4922	902·3811
64	·8710	331·3840	9	591·3840	·1290	64	64	·4859	911·8670
	·8646				·1354			·4795	
66		341·2486	10	541·2486		66	64		921·3465
63	·8580	351·1066	1	491·1066	·1420	63	63	·4731	930·8196
66	·8517	360·9583	2	440·9583	·1483	66	64	·4668	940·2864
64	·8451	370·8034	3	390·8034	·1549	64	64	·4604	949·7468
64	·8387	380·6421	4	340·6421	·1613	65	63	·4540	959·2008
65	·8322	390·4743	15	290·4743	·1678	64	64	·4477	968·6485
65	·8258	400·3001	6	240·3001	·1742	64	63	·4413	978·0898
65	·8193	410·1194	7	190·1194	·1807	65	64	·4350	987·5248
64	·8128	419·9322	8	139·9322	·1872	64	63	·4286	152996·9534
64	·8064	429·7386	9	89·7386	·1936	64	64	·4223	153006·3757
	·8000				·2000			·4159	
65		439·5386	20	39·5386		65	63		015·7916
65	·7935	449·3321	1	10·6679	·2065	65	64	·4096	025·2012
64	·7870	459·1191	2	60·8809	·2130	64	63	·4032	034·6044
64	·7806	468·8997	3	111·1003	·2194	64	63	·3969	044·0013
65	·7742	478·6739	4	161·3261	·2258	65	64	·3906	053·3919
64	·7677	488·4416	25	211·5584	·2323	64	64	·3842	062·7761
65	·7613	498·2029	6	261·7971	·2387	65	62	·3778	072·1539
64	·7548	507·9577	7	312·0423	·2452	64	64	·3716	081·5255
65	·7484	517·7061	8	362·2939	·2516	65	64	·3652	090·8907
64	·7419	527·4480	9	412·5520	·2581	64	63	·3588	100·2495
	·7355				·2645			·3525	
64		537·1835	30	462·8165		64	63		109·6020
65	·7291	546·9126	1	513·0874	·2709	65	63	·3462	118·9482
64	·7226	556·6352	2	563·3648	·2774	64	64	·3399	128·2881
64	·7162	566·3514	3	613·6486	·2838	64	62	·3335	137·6216
64	·7098	576·0612	4	663·9388	·2902	64	64	·3273	146·9489
65	·7034	585·7646	35	714·2354	·2966	65	63	·3209	156·2698
64	·6969	595·4615	6	764·5385	·3031	64	64	·3146	165·5844
64	·6905	605·1520	7	814·8480	·3095	64	63	·3082	174·8926
64	·6841	614·8361	8	865·1639	·3159	64	62	·3019	184·1945
65	·6777	624·5138	9	915·4862	·3223	65	64	·2957	193·4902
	·6712				·3288			·2893	
63		634·1850	40	965·8150		63	64		202·7795
65	·6649	643·8499	1	1016·1501	·3351	65	62	·2829	212·0624
64	·6584	653·5083	2	066·4917	·3416	64	63	·2767	221·3391
64	·6520	663·1603	3	116·8397	·3480	64	63	·2704	230·6095
64	·6456	672·8059	4	167·1941	·3544	64	64	·2641	239·8736
65	·6392	682·4451	45	217·5549	·3608	65	62	·2577	249·1313
63	·6327	692·0778	6	267·9222	·3673	63	64	·2515	258·3828
64	·6264	701·7042	7	318·2958	·3736	64	62	·2451	267·6279
65	·6200	711·3242	8	368·6758	·3800	65	64	·2389	276·8668
63	·6135	720·9377	9	419·0623	·3865	63	62	·2325	286·0993
	·6072				·3928			·2263	
65		730·5449	50	469·4551		65	63		295·3256
63	·6007	740·1456	1	519·8544	·3993	63	63	·2200	304·5456
64	·5944	749·7400	2	570·2600	·4056	64	63	·2137	313·7593
65	·5880	759·3280	3	620·6720	·4120	65	64	·2074	322·9667
63	·5815	768·9095	4	671·0905	·4185	63	62	·2010	332·1677
64	·5752	778·4847	55	721·5153	·4248	64	63	·1948	341·3625
64	·5688	788·0535	6	771·9465	·4312	64	62	·1885	350·5510
64	·5624	797·6159	7	822·3841	·4376	64	64	·1823	359·7333
64	·5560	807·1719	8	872·8281	·4440	64	62	·1759	368·9092
63	·5496	816·7215	9	923·2785	·4504	63	63	·1697	378·0789
	9·5433	152826·2648	60	1973·7352	50·4567			9·1634	153387·2423

′	−43°.	Diff.	Δ²	Δ²	Diff.	44°	′	−44°	Diff.	Δ²
	″	″			″	″		″	″	
0	1973·7352		65	63		153387·2423	0	5012·7577		63
		50·4632			9·1571				50·8429	
1	2024·1984	·4695	63	63	·1508	396·3994	1	063·6006	·8492	63
2	074·6679	·4759	64	62	·1446	405·5502	2	114·4498	·8554	62
3	125·1438	·4823	64	63	·1383	414·6948	3	165·3052	·8617	63
4	175·6261	·4886	63	63	·1320	423·8331	4	216·1669	·8680	63
5	226·1147	·4950	64	63	·1257	432·9651	5	267·0349	·8743	63
6	276·6097	·5014	64	62	·1195	442·0908	6	317·9092	·8805	62
7	327·1111	·5078	64	63	·1132	451·2103	7	368·7897	·8868	63
8	377·6189	·5141	63	62	·1070	460·3235	8	419·6765	·8930	62
9	428·1330	·5205	64	63	·1007	469·4305	9	470·5695	·8993	63
10	478·6535		64	63		478·5312	10	521·4688		63
		·5269			·0944				·9056	
1	529·1804	·5332	63	62	·0882	487·6256	1	572·3744	·9118	62
2	579·7136	·5396	64	63	·0819	496·7138	2	623·2862	·9181	63
3	630·2532	·5460	64	62	·0757	505·7957	3	674·2043	·9243	62
4	680·7992	·5523	64	63	·0694	514·8714	4	725·1286	·9306	63
15	731·3515	·5587	63	63	·0631	523·9408	15	776·0592	·9369	63
6	781·9102	·5650	64	62	·0569	533·0039	6	826·9961	·9431	62
7	832·4752	·5714	63	62	·0507	542·0608	7	877·9392	·9493	62
8	883·0466	·5777	64	63	·0444	551·1115	8	928·8885	·9556	63
9	933·6243	·5841		62	·0382	560·1559	9	5979·8441	·9618	62
20	2984·2084		63	63		569·1941	20	6030·8059		63
		·5904			·0319				·9681	
1	3034·7988	·5968	64	62	·0257	578·2260	1	081·7740	·9743	62
2	085·3956	·6031	63	62	·0195	587·2517	2	132·7483	·9805	62
3	135·9987	·6094	63	63	·0132	596·2712	3	183·7288	·9868	63
4	186·6081	·6158	64	62	·0070	605·2844	4	234·7156	·9930	62
25	237·2239	·6222	64	63	9·0007	614·2914	25	285·7086	50·9993	63
6	287·8461	·6284	62	62	8·9945	623·2921	6	336·7079	51·0055	62
7	338·4745	·6348	64	62	·9883	632·2866	7	387·7134	·0117	62
8	389·1093	·6412	64	62	·9821	641·2749	8	438·7251	·0179	62
9	439·7505	·6475	63	63	·9758	650·2570	9	489·7430	·0242	63
30	490·3980		63	61		659·2328	30	540·7672		61
		·6538			·9697				·0303	
1	541·0518	·6601	63	63	·9634	668·2025	1	591·7975	·0366	63
2	591·7119	·6665	64	63	·9571	677·1659	2	642·8341	·0429	63
3	642·3784	·6727	62	61	·9510	686·1230	3	693·8770	·0490	61
4	693·0511	·6791	64	63	·9447	695·0740	4	744·9260	·0553	63
35	743·7302	·6854	63	62	·9385	704·0187	35	795·9813	·0615	62
6	794·4156	·6918	64	62	·9323	712·9572	6	847·0428	·0677	62
7	845·1074	·6981	63	62	·9261	721·8895	7	898·1105	·0739	62
8	895·8055	·7043	62	62	·9199	730·8156	8	6949·1844	·0801	62
9	946·5098	·7107	64	63	·9136	739·7355	9	7000·2645	·0864	63
40	3997·2205		64	61		748·6491	40	051·3509		61
		·7171			·9075				·0925	
1	4047·9376	·7233	62	62	·9013	757·5566	1	102·4434	·0987	62
2	098·6609	·7296	63	62	·8951	766·4579	2	153·5421	·1049	62
3	149·3905	·7359	64	63	·8888	775·3530	3	204·6470	·1112	63
4	200·1264	·7423	62	61	·8827	784·2418	4	255·7582	·1173	61
45	250·8687	·7485	64	63	·8764	793·1245	45	306·8755	·1236	63
6	301·6172	·7549	62	61	·8703	802·0009	6	357·9991	·1297	61
7	352·3721	·7611	64	63	·8640	810·8712	7	409·1288	·1360	63
8	403·1332	·7675	62	61	·8579	819·7352	8	460·2648	·1421	61
9	453·9007	·7737		62	·8517	828·5931	9	511·4069	·1483	62
50	504·6744		63	62		837·4448	50	562·5552		62
		·7800			·8455				·1545	
1	555·4544	·7863	63	62	·8393	846·2903	1	613·7097	·1607	62
2	606·2407	·7926	63	62	·8331	855·1296	2	664·8704	·1669	62
3	657·0333	·7990	64	61	·8270	863·9627	3	716·0373	·1730	61
4	707·8323	·8052	62	63	·8207	872·7897	4	767·2103	·1793	63
55	758·6375	·8115	63	61	·8146	881·6104	55	818·3896	·1854	61
6	809·4490	·8177	62	62	·8084	890·4250	6	869·5750	·1916	62
7	860·2667	·8241	64	61	·8023	899·2334	7	920·7666	·1977	61
8	911·0908	·8303	62	63	·7960	908·0357	8	7971·9643	·2040	63
9	4961·9211		63	61		916·8317	9	8023·1683		61
		50·8366			8·7899				51·2101	
60	5012·7577					153925·6216	60	8074·3784		

Δ°.	Diff.	45°.	′	−45°.	Diff.	Δ°.	Δ°.	Diff.	46°.
	″	″		″	″			″	″
62	8·7837	153925·6216	0	8074·3784	51·2163	62	60	8·4168	154441·7871
61	·7776	934·4053	1	125·5947	·2224	61	61	·4107	450·2039
63	·7713	943·1829	2	176·8171	·2287	63	61	·4046	458·6146
61	·7652	951·9542	3	228·0458	·2348	61	60	·3986	467·0192
61	·7591	960·7194	4	279·2806	·2409	61	60	·3926	475·4178
62	·7529	969·4785	5	330·5215	·2471	62	61	·3865	483·8104
62	·7467	978·2314	6	381·7686	·2533	62	61	·3804	492·1969
61	·7406	986·9781	7	433·0219	·2594	61	60	·3744	500·5773
62	·7344	153995·7187	8	484·2813	·2656	62	60	·3684	508·9517
62	·7282	154004·4531	9	535·5469	·2718	62	61	·3623	517·3201
61	·7221	013·1813	10	586·8187	·2779	61	61	·3562	525·6824
61	·7160	021·9034	1	638·0966	·2840	61	60	·3502	534·0386
62	·7098	030·6194	2	689·3806	·2902	62	60	·3442	542·3888
61	·7037	039·3292	3	740·6708	·2963	61	61	·3381	550·7330
62	·6975	048·0329	4	791·9671	·3025	62	60	·3321	559·0711
62	·6913	056·7304	15	843·2696	·3087	62	60	·3261	567·4032
61	·6852	065·4217	6	894·5783	·3148	61	61	·3200	575·7293
61	·6791	074·1069	7	945·8931	·3209	61	60	·3140	584·0493
61	·6730	082·7860	8	8997·2140	·3270	61	60	·3080	592·3633
62	·6668	091·4590	9	9048·5410	·3332	62	61	·3019	600·6713
61	·6607	100·1258	20	099·8742	·3393	61	59	·2960	608·9732
62	·6545	108·7865	1	151·2135	·3455	62	61	·2899	617·2692
61	·6484	117·4410	2	202·5590	·3516	61	61	·2838	625·5591
61	·6423	126·0894	3	253·9106	·3577	61	59	·2779	633·8429
61	·6362	134·7317	4	305·2683	·3638	61	61	·2718	642·1208
62	·6300	143·3679	25	356·6321	·3700	62	60	·2658	650·3926
61	·6239	151·9979	6	408·0021	·3761	61	60	·2598	658·6584
61	·6178	160·6218	7	459·3782	·3822	61	60	·2538	666·9182
62	·6116	169·2396	8	510·7604	·3884	62	60	·2478	675·1720
60	·6056	177·8512	9	562·1488	·3944	60	60	·2418	683·4198
62	·5994	186·4568	30	613·5432	·4006	62	60	·2358	691·6616
61	·5933	195·0562	1	664·9438	·4067	61	61	·2297	699·8974
61	·5872	203·6495	2	716·3505	·4128	61	60	·2237	708·1271
61	·5811	212·2367	3	767·7633	·4189	61	59	·2178	716·3508
61	·5750	220·8178	4	819·1822	·4250	61	60	·2118	724·5686
61	·5689	229·3928	35	870·6072	·4311	61	61	·2057	732·7804
61	·5628	237·9617	6	922·0383	·4372	61	59	·1998	740·9861
62	·5566	246·5245	7	9973·4755	·4434	62	60	·1938	749·1859
60	·5506	255·0811	8	10024·9189	·4494	60	61	·1877	757·3797
62	·5444	263·6317	9	076·3683	·4556	62	59	·1818	765·5674
60	·5384	272·1761	40	127·8239	·4616	60	60	·1758	773·7492
61	·5323	280·7145	1	179·2855	·4677	61	60	·1698	781·9250
62	·5261	289·2468	2	230·7532	·4739	62	59	·1639	790·0948
60	·5201	297·7729	3	282·2271	·4799	60	61	·1578	798·2587
61	·5140	306·2930	4	333·7070	·4860	61	59	·1519	806·4165
61	·5079	314·8070	45	385·1930	·4921	61	60	·1459	814·5684
61	·5018	323·3149	6	436·6851	·4982	61	60	·1399	822·7143
61	·4957	331·8167	7	488·1833	·5043	61	60	·1339	830·8542
60	·4897	340·3124	8	539·6876	·5103	60	60	·1279	838·9881
62	·4835	348·8021	9	591·1979	·5165	62	59	·1220	847·1160
60	·4775	357·2856	50	642·7144	·5225	60	60	·1160	855·2380
61	·4714	365·7631	1	694·2369	·5286	61	59	·1101	863·3540
61	·4653	374·2345	2	745·7655	·5347	61	60	·1041	871·4641
60	·4593	382·6998	3	797·3002	·5407	60	60	·0981	879·5682
61	·4532	391·1591	4	848·8409	·5468	61	60	·0921	887·6663
61	·4471	399·6123	55	900·3877	·5529	61	59	·0862	895·7584
61	·4410	408·0594	6	10951·9406	·5590	61	60	·0802	903·8446
60	·4350	416·5004	7	11003·4996	·5650	60	59	·0743	911·9248
61	·4289	424·9354	8	055·0646	·5711	61	60	·0683	919·9991
61	8·4228	433·3643	9	106·6357	51·5772	61	59	8·0624	928·0674
		154441·7871	60	11158·2129					154936·1298

−46.	Diff.	Δ°.	Δ°.	Diff.	47°.	′	−47°.	Diff.	Δ°.
11158″2129	″			′	154936″1298		14263″8702	″	
	51·5832	60	60	8·0564		0		51·9436	60
209·7961	·5893	61	59	·0505	944·1862	1	315·8138	·9495	59
261·3854	·5954	61	60	·0445	952·2367	2	367·7633	·9555	60
312·9808	·6014	60	59	·0386	960·2812	3	419·7188	·9614	59
364·5822	·6074	60	60	·0326	968·3198	4	471·6802	·9674	60
416·1896	·6135	61	59	·0267	976·3524	5	523·6476	·9733	59
467·8031	·6196	61	60	·0207	984·3791	6	575·6209	·9793	60
519·4227	·6256	60	59	·0148	154992·3998	7	627·6002	·9852	59
571·0483	·6316	60	59	·0089	155000·4146	8	679·5854	·9911	59
622·6799	·6377	61	60	8·0029	008·4235.	9	·731·5765	51·9971	60
674·3176	·6438	61	59	7·9970	016·4264	10	783·5736	52·0030	59
725·9614	·6498	60	59	·9911	024·4234	1	835·5766	·0089	59
777·6112	·6558	60	60	·9851	032·4145.	2	887·5855	·0149	60
829·2670	·6619	61	59	·9792	040·3996	3	939·6004	·0208	59
880·9289	·6679	60	59	·9733	048·3788	4	14991·6212	·0267	59
932·5968	·6739	60	59	·9674	056·3521	15	15043·6479	·0326	59
11984·2707	·6800	61	60	·9614	064·3195.	6	095·6805	·0386	60
12035·9507	·6860	60	59	·9555	072·2809	7	147·7191	·0445	59
087·6367	·6920	60	59	·9496	080·2364	8	199·7636	·0504	59
139·3287	·6981	61	59	·9437	088·1860	9	251·8140	·0563	59
191·0268	·7040	59	59	·9378	096·1297	20	303·8703	·0622	59
242·7308	·7101	61	59	·9319	104·0675	1	355·9325.	·0681	59
294·4409	·7162	61	60	·9259	111·9994	2	408·0006	·0741	60
346·1571	·7221	59	58	·9201	119·9253	3	460·0747	·0799	58
397·8792	·7282	61	60	·9141	127·8454	4	512·1546	·0859	60
449·6074	·7342	60	59	·9082	135·7595	25	564·2405.	·0918	59
501·3416	·7402	60	58	·9024	143·6677	6	616·3323	·0976	58
553·0818	·7462	60	60	·8964	151·5701	7	668·4299	·1036	60
604·8280	·7522	60	59	·8905	159·4665.	8	720·5335	·1095	59
656·5802	·7582	60	59	·8846	167·3570	9	772·6430	·1154	59
708·3384	·7642	60	59	·8787	175·2416	30	824·7584	·1213	59
760·1026	·7703	61	58	·8729	183·1203	1	876·8797	·1271	58
811·8729	·7763	60	59	·8670	190·9932	2	929·0068	·1330	59
863·6492	·7822	59	60	·8610	198·8602	3	15981·1398	·1390	60
915·4314	·7882	60	58	·8552	206·7212	4	16033·2788	·1448	58
12967·2196	·7943	61	59	·8493	214·5764	35	085·4236	·1507	59
13019·0139	·8002	59	59	·8434	222·4257	6	137·5743	·1566	59
070·8141	·8062	60	59	·8375	230·2691	7	189·7309	·1625	59
122·6203	·8123	61	59	·8316	238·1066	8	241·8934	·1684	59
174·4326	·8182	59	58	·8258	245·9382	9	294·0618	·1742	58
226·2508	·8242	60	60	·8198	253·7640	40	346·2360	·1802	60
278·0750.	·8302	60	58	·8140	261·5838	1	398·4162	·1860	58
329·9052	·8361	59	58	·8082	269·3978	2	450·6022	·1918	58
381·7413	·8422	61	60	·8022	277·2060	3	502·7940	·1978	60
433·5835	·8481	59	58	·7964	285·0082	4	554·9918	·2036	58
485·4316	·8541	60	59	·7905	292·8046	45	607·1954	·2095	59
537·2857	·8601	60	58	·7847	300·5951	6	659·4049	·2153	58
589·1458	·8661	60	59	·7788	308·3798	7	711·6202	·2212	59
641·0119	·8721	60	59	·7729	316·1586	8	763·8414	·2271	59
692·8840	·8780	59	58	·7671	323·9315	9	816·0685.	·2329	58
744·7620	·8840	60	59	·7612	331·6986	50	868·3014	·2388	59
796·6460	·8899	59	58	·7554	339·4598	1	920·5402	·2446	58
848·5359	·8959	60	59	·7495	347·2152	2	16972·7848	·2505	59
900·4318	·9019	60	59	·7436	354·9647	3	17025·0353	·2564	59
13952·3337	·9079	60	58	·7378	362·7083	4	077·2917	·2622	58
14004·2416	·9138	59	58	·7320	370·4461	55	129·5539	·2680	58
056·1554	·9198	60	59	·7261	378·1781	6	181·8219	·2739	59
108·0752	·9257	59	59	·7202	385·9042	7	234·0958	·2798	59
160·0009	·9317	60	58	·7144	393·6244	8	286·3756	·2856	58
211·9326	51·9376	59	58	7·7086	401·3388	9	338·6612	52·2914	58
14263·8702					155409·0474	60	17390·9526		

Δ°.	Diff.	48°.	′	−48°.	Diff.	Δ°.	Δ°.	Diff.	49°.
	″	″		″	″			″	″
58		155409·0474	0	17390·9526		58	56		155860·9442
	7·7028				52·2972			7·3559	
59		416·7502	1	443·2498		59	58		868·3001
	·6969				·3031			·3501	
59		424·4471	2	495·5529		59	57		875·6502
	·6910				·3090			·3444	
57		432·1381	3	547·8619		57	57		882·9946
	·6853				·3147			·3387	
59		439·8234	4	600·1766		59	57		890·3333
	·6794				·3206			·3330	
59		447·5028	5	652·4972		59	58		897·6663
	·6735				·3265			·3272	
58		455·1763	6	704·8237		58	56		904·9935
	·6677				·3323			·3216	
57		462·8440	7	757·1560		57	58		912·3151
	·6620				·3380			·3158	
59		470·5060	8	809·4940		59	57		919·6309
	·6561				·3439			·3101	
59		478·1621	9	861·8379		59	57		926·9410
	·6502				·3498			·3044	
57		485·8123	10	914·1877		57	57		934·2454
	·6445				·3555			·2987	
59		493·4568	1	17966·5432		59	57		941·5441
	·6386				·3614			·2930	
58		501·0954	2	18018·9046		58	57		948·8371
	·6328				·3672			·2873	
58		508·7282	3	071·2718		58	57		956·1244
	·6270				·3730			·2816	
58		516·3552	4	123·6448		58	57		963·4060
	·6212				·3788			·2759	
58		523·9764	15	176·0236		58	57		970·6819
	·6154				·3846			·2702	
59		531·5918	6	228·4082		59	57		977·9521
	·6095				·3905			·2645	
57		539·2013	7	280·7987		57	57		985·2166
	·6038				·3962			·2588	
59		546·8051	8	333·1949		59	56		992·4754
	·5979				·4021			·2532	
57		554·4030	9	385·5970		57	58		155999·7286
	·5922				·4078			·2474	
59		561·9952	20	438·0048		59	56		156006·9760
	·5863				·4137			·2418	
57		569·5815	1	490·4185		57	58		014·2178
	·5806				·4194			·2360	
58		577·1621	2	542·8379		58	56		021·4538
	·5748				·4252			·2304	
59		584·7369	3	595·2631		59	57		028·6842
	·5689				·4311			·2247	
57		592·3058	4	647·6942		57	57		035·9089
	·5632				·4368			·2190	
59		599·8690	25	700·1310		59	56		043·1279
	·5573				·4427			·2134	
57		607·4263	6	752·5737		57	58		050·3413
	·5516				·4484			·2076	
58		614·9779	7	805·0221		58	56		057·5489
	·5458				·4542			·2020	
58		622·5237	8	857·4763		58	56		064·7509
	·5400				·4600			·1964	
58		630·0637	9	909·9363		58	58		071·9473
	·5342				·4658			·1906	
57		637·5979	30	18962·4021		57	56		079·1379
	·5285				·4715			·1850	
59		645·1264	1	19014·8736		59	57		086·3229
	·5226				·4774			·1793	
57		652·6490	2	067·3510		57	56		093·5022
	·5169				·4831			·1737	
58		660·1659	3	119·8341		58	57		100·6759
	·5111				·4889			·1680	
58		667·6770	4	172·3230		58	57		107·8439
	·5053				·4947			·1623	
57		675·1823	35	224·8177		57	56		115·0062
	·4996				·5004			·1567	
58		682·6819	6	277·3181		58	57		122·1629
	·4938				·5062			·1510	
58		690·1757	7	329·8243		58	56		129·3139
	·4880				·5120			·1454	
58		697·6637	8	382·3363		58	57		136·4593
	·4822				·5178			·1397	
57		705·1459	9	434·8541		57	56		143·5990
	·4765				·5235			·1341	
58		712·6224	40	487·3776		58	57		150·7331
	·4707				·5293			·1284	
57		720·0931	1	539·9069		57	56		157·8615
	·4650				·5350			·1228	
58		727·5581	2	592·4419		58	57		164·9843
	·4592				·5408			·1171	
58		735·0173	3	644·9827		58	56		172·1014
	·4534				·5466			·1115	
57		742·4707	4	697·5293		57	57		179·2129
	·4477				·5523			·1058	
58		749·9184	45	750·0816		58	56		186·3187
	·4419				·5581			·1002	
57		757·3603	6	802·6397		57	56		193·4189
	·4362				·5638			·0946	
58		764·7965	7	855·2035		58	57		200·5135
	·4304				·5696			·0889	
57		772·2269	8	907·7731		57	56		207·6024
	·4247				·5753			·0833	
58		779·6516	9	19960·3484		58	56		214·6857
	·4189				·5811			·0777	
57		787·0705	50	20012·9295		57	56		221·7634
	·4132				·5868			·0721	
57		794·4837	1	065·5163		57	57		228·8355
	·4075				·5925			·0664	
58		801·8912	2	118·1088		58	56		235·9019
	·4017				·5983			·0608	
57		809·2929	3	170·7071		57	57		242·9627
	·3960				·6040			·0551	
58		816·6889	4	223·3111		58	55		250·0178
	·3902				·6098			·0496	
57		824·0791	55	275·9209		57	57		257·0674
	·3845				·6155			·0439	
58		831·4636	6	328·5364		58	56		264·1113
	·3787				·6213			·0383	
56		838·8423	7	381·1577		56	56		271·1496
	·3731				·6269			·0327	
58		846·2154	8	433·7846		58	56		278·1823
	·3673				·6327			·0271	
58		853·5827	9	486·4173		58	56		285·2094
	7·3615				52·6385			7·0215	
		155860·9442	60	20539·0558					156292·2309

−49°.	Diff.	Δ².	Δ².	Diff.	50°.	′	−50°.	Diff.	Δ².
″	″			″	″		″	″	
20539·0558	52·6441	56	56	7·0159	156292·2309	0	23707·7691	52·9841	56
591·6999	·6499	58	57	·0102	299·2468	1	760·7532	·9898	57
644·3498	·6556	57	56	7·0046	306·2570	2	813·7430	52·9954	56
697·0054	·6613	57	55	6·9991	313·2616	3	866·7384	53·0009	55
749·6667	·6670	57	57	·9934	320·2607	4	919·7393	·0066	57
802·3337	·6728	58	55	·9879	327·2541	5	23972·7459	·0121	55
855·0065.	·6784	56	57	·9822	334·2420	6	24025·7580	·0178	57
907·6849	·6842	58	55	·9767	341·2242	7	078·7758	·0233	55
20960·3691	·6899	57	57	·9710	348·2009	8	131·7991	·0290	57
21013·0590	·6956	57	55	·9655	355·1719	9	184·8281	·0345	55
065·7546	·7013	57	56	·9599	362·1374	10	237·8626	·0401	56
118·4559	·7070	57	56	·9543	369·0973	1	290·9027	·0457	56
171·1629	·7127	57	56	·9487	376·0516	2	343·9484	·0513	56
223·8756	·7184	57	56	·9431	383·0003	3	396·9997	·0569	56
276·5940	·7241	57	56	·9375	389·9434	4	450·0566	·0625	56
329·3181	·7298	57	55	·9320	396·8809	15	503·1191	·0680	55
382·0479	·7355	57	56	·9264	403·8129	6	556·1871	·0736	56
434·7834	·7412	57	56	·9208	410·7393	7	609·2607	·0792	56
487·5246	·7468	56	56	·9152	417·6601	8	662·3399	·0848	56
540·2714	·7526	58	56	·9096	424·5753	9	715·4247	·0904	56
593·0240	·7582	56	55	·9041	431·4849	20	768·5151	·0959	55
645·7822	·7640	58	56	·8985	438·3890	1	821·6110	·1015	56
698·5462	·7696	56	55	·8930	445·2875	2	874·7125	·1070	55
751·3158	·7753	57	56	·8874	452·1805	3	927·8195	·1126	56
804·0911	·7810	57	56	·8818	459·0679	4	24980·9321	·1182	56
856·8721	·7866	56	56	·8762	465·9497	25	25034·0503	·1238	56
909·6587	·7924	58	55	·8707	472·8259	6	087·1741	·1293	55
21962·4511	·7980	56	55	·8652	479·6966	7	140·3034	·1348	55
22015·2491	·8036	56	56	·8596	486·5618	8	193·4382	·1404	56
068·0527	·8094	58	56	·8540	493·4214	9	246·5786	·1460	56
120·8621	·8150	56	55	·8485	500·2754	30	299·7246	·1515	55
173·6771	·8207	57	56	·8429	507·1239	1	352·8761	·1571	56
226·4978	·8263	56	55	·8374	513·9668	2	406·0332	·1626	55
279·3241	·8320	57	55	·8319	520·8042	3	459·1958	·1681	55
332·1561	·8377	57	56	·8263	527·6361	4	512·3639	·1737	56
384·9938	·8433	56	56	·8207	534·4624	35	565·5376	·1793	56
437·8371	·8490	57	54	·8153	541·2831	6	618·7169	·1847	54
490·6861	·8546	56	56	·8097	548·0984	7	671·9016	·1903	56
543·5407	·8603	57	56	·8041	554·9081	8	725·0919	·1959	56
596·4010	·8659	56	55	·7986	561·7122	9	778·2878	·2014	55
649·2669	·8716	57	55	·7931	568·5108	40	831·4892	·2069	55
702·1385	·8772	56	55	·7876	575·3039	1	884·6961	·2124	55
755·0157	·8829	57	56	·7820	582·0915.	2	937·9085	·2180	56
807·8986	·8885	56	55	·7765	588·8735	3	25991·1265	·2235	55
860·7871	·8942	57	55	·7710	595·6500	4	26044·3500	·2290	55
913·6813	·8998	56	55	·7655	602·4210	45	097·5790	·2345	55
22966·5811	·9054	56	56	·7599	609·1865.	6	150·8135	·2401	56
23019·4865	·9111	57	55	·7544	615·9464	7	204·0536	·2456	55
072·3976	·9167	56	55	·7489	622·7008	8	257·2992	·2511	55
125·3143	·9223	56	55	·7434	629·4497	9	310·5503	·2566	55
178·2366	·9279	56	55	·7379	636·1931	50	363·8069	·2621	55
231·1645	·9336	57	55	·7324	642·9310	1	417·0690	·2676	55
284·0981	·9392	56	55	·7269	649·6634	2	470·3366	·2731	55
337·0373	·9449	57	56	·7213	656·3903	3	523·6097	·2787	56
389·9822	·9504	55	54	·7159	663·1116	4	576·8884	·2841	54
442·9326	·9561	57	56	·7103	669·8275.	55	630·1725	·2897	56
495·8887	·9617	56	54	·7049	676·5378	6	683·4622	·2951	54
548·8504	·9673	56	56	·6993	683·2427	7	736·7573	·3007	56
601·8177	·9729	56	54	·6939	689·9420	8	790·0580	·3061	54
654·7906	52·9785		55	6·6884	696·6359	9	843·3641	53·3116	55
23707·7691					156703·3243	60	26896·6757		

Δ°.	Diff.	51°.	′	−51°.	Diff.	Δ°.
	″	″		″	″	
56	6·6828	156703·3243	0	26896·6757	53·3172	56
54	·6774	710·0071	1	26949·9929	·3226	54
55	·6719	716·6845	2	27003·3155	·3281	55
55	·6664	723·3564	3	056·6436	·3336	55
55	·6609	730·0228	4	109·9772	·3391	55
54	·6555	736·6837	5	163·3163	·3445	54
55	·6500	743·3392	6	216·6608	·3500	55
56	·6444	749·9892	7	270·0108	·3556	56
54	·6390	756·6336	8	323·3664	·3610	54
54	·6336	763·2726	9	376·7274	·3664	54
55	·6281	769·9062	10	430·0938	·3719	55
55	·6226	776·5343	1	483·4657	·3774	55
55	·6171	783·1569	2	536·8431	·3829	55
54	·6117	789·7740	3	590·2260	·3883	54
55	·6062	796·3857	4	643·6143	·3938	55
55	·6007	802·9919	15	697·0081	·3993	55
54	·5953	809·5926	6	750·4074	·4047	54
55	·5898	816·1879	7	803·8121	·4102	55
55	·5843	822·7777	8	857·2223	·4157	55
54	·5789	829·3620	9	910·6380	·4211	54
54	·5735	835·9409	20	27964·0591	·4265	54
55	·5680	842·5144	1	28017·4856	·4320	55
54	·5626	849·0824	2	070·9176	·4374	54
55	·5571	855·6450	3	124·3550	·4429	55
55	·5516	862·2021	4	177·7979	·4484	55
54	·5462	868·7537	25	231·2463	·4538	54
54	·5408	875·2999	6	284·7001	·4592	54
54	·5354	881·8407	7	338·1593	·4646	54
55	·5299	888·3761	8	391·6239	·4701	55
55	·5244	894·9060	9	445·0940	·4756	55
53	·5191	901·4304	30	498·5696	·4809	53
55	·5136	907·9495	1	552·0505	·4864	55
54	·5082	914·4631	2	605·5369	·4918	54
55	·5027	920·9713	3	659·0287	·4973	55
53	·4974	927·4740	4	712·5260	·5026	53
55	·4919	933·9714	35	766·0286	·5081	55
55	·4864	940·4633	6	819·5367	·5136	55
53	·4811	946·9497	7	873·0503	·5189	53
54	·4757	953·4308	8	926·5692	·5243	54
55	·4702	959·9065	9	28980·0935	·5298	55
54	·4648	966·3767	40	29033·6233	·5352	54
53	·4595	972·8415	1	087·1585	·5405	53
55	·4540	979·3010	2	140·6990	·5460	55
55	·4485	985·7550	3	194·2450	·5515	55
53	·4432	992·2035	4	247·7965	·5568	53
54	·4378	156998·6467	45	301·3533	·5622	54
54	·4324	157005·0845	6	354·9155	·5676	54
54	·4270	011·5169	7	408·4831	·5730	54
54	·4216	017·9439	8	462·0561	·5784	54
54	·4162	024·3655	9	515·6345	·5838	54
54	·4108	030·7817	50	569·2183	·5892	54
54	·4054	037·1925	1	622·8075	·5946	54
54	·4000	043·5979	2	676·4021	·6000	54
53	·3947	049·9979	3	730·0021	·6053	53
54	·3893	056·3926	4	783·6074	·6107	54
55	·3838	062·7819	55	837·2181	·6162	55
53	·3785	069·1657	6	890·8343	·6215	53
53	·3732	075·5442	7	944·4558	·6268	53
55	·3677	081·9174	8	29998·0826	·6323	55
53	6·3624	088·2851	9	30051·7149	53·6376	53
		157094·6475	60	30105·3525		

Δ′	Diff.	52°.
	″	
54	6·3570	157094·6475
54	·3516	101·0045
54	·3462	107·3561
53	·3409	113·7023
54	·3355	120·0432
53	·3302	126·3787
54	·3248	132·7089
54	·3194	139·0337
53	·3141	145·3531
54	·3087	151·6672
53	·3034	157·9759
54	·2980	164·2793
53	·2927	170·5773
54	·2873	176·8700
53	·2820	183·1573
53	·2767	189·4393
54	·2713	195·7160
54	·2659	201·9873
53	·2606	208·2532
53	·2553	214·5138
53	·2500	220·7691
54	·2446	227·0191
53	·2393	233·2637
53	·2340	239·5030
54	·2286	245·7370
52	·2234	251·9656
54	·2180	258·1890
53	·2127	264·4070
54	·2073	270·6197
52	·2021	276·8270
53	·1968	283·0291
54	·1914	289·2259
53	·1861	295·4173
53	·1808	301·6034
53	·1755	307·7842
53	·1702	313·9597
52	·1650	320·1299
54	·1596	326·2949
53	·1543	332·4545
53	·1490	338·6088
53	·1437	344·7578
52	·1385	350·9015
54	·1331	357·0400
52	·1279	363·1731
53	·1226	369·3010
53	·1173	375·4236
53	·1120	381·5409
53	·1067	387·6529
52	·1015	393·7596
53	·0962	399·8611
53	·0909	405·9573
52	·0857	412·0482
53	·0804	418·1339
53	·0751	424·2143
53	·0698	430·2894
52	·0646	436·3592
53	·0593	442·4238
52	·0541	448·4831
53	·0488	454·5372
52	6·0436	460·5860
		157466·6296

−52°.	Diff.	Δ².	Δ².	Diff.	53°.	′	−53°.	Diff.	Δ².
″	″			″	″		″	″	
30105·3525	53·6430	54	53	6·0383	157466·6296	0	33333·3704	53·9617	53
158·9955	·6484	54	53	·0330	472·6679	1	387·3321	·9670	53
212·6439	·6538	54	52	·0278	478·7009	2	441·2991	·9722	52
266·2977	·6591	53	52	·0226	484·7287	3	495·2713	·9774	52
319·9568	·6645	54	53	·0173	490·7513	4	549·2487	·9827	53
373·6213	·6698	53	52	·0121	496·7686	5	603·2314	·9879	52
427·2911	·6752	54	52	·0069	502·7807	6	657·2193	·9931	52
480·9663	·6806	54	53	6·0016	508·7876	7	711·2124	53·9984	53
534·6469	·6859	53	53	5·9963	514·7892	8	765·2108	54·0037	53
588·3328	·6913	54	51	·9912	520·7855	9	819·2145	·0088	51
642·0241	·6966	53	53	·9859	526·7767	10	873·2233	·0141	53
695·7207	·7020	54	53	·9806	532·7626	1	927·2374	·0194	53
749·4227	·7073	53	51	·9755	538·7432	2	33981·2568	·0245	51
803·1300	·7127	54	53	·9702	544·7187	3	34035·2813	·0298	53
856·8427	·7180	53	52	·9650	550·6889	4	089·3111	·0350	52
910·5607	·7233	53	52	·9598	556·6539	15	143·3461	·0402	52
30964·2840	·7287	54	53	·9545	562·6137	6	197·3863	·0455	53
31018·0127	·7341	54	51	·9494	568·5682	7	251·4318	·0506	51
071·7468	·7394	53	53	·9441	574·5176	8	305·4824	·0559	53
125·4862	·7447	53	52	·9389	580·4617	9	359·5383	·0611	52
179·2309	·7500	53	52	·9337	586·4006	20	413·5994	·0663	52
232·9809	·7554	54	52	·9285	592·3343	1	467·6657	·0715	52
286·7363	·7607	53	52	·9233	598·2628	2	521·7372	·0767	52
340·4970	·7660	53	52	·9181	604·1861	3	575·8139	·0819	53
394·2630	·7714	54	53	·9128	610·1042	4	629·8958	·0872	51
448·0344	·7766	52	51	·9077	616·0170	25	683·9830	·0923	52
501·8110	·7820	54	52	·9025	621·9247	6	738·0753	·0975	53
555·5930	·7873	53	53	·8972	627·8272	7	792·1728	·1028	51
609·3803	·7927	54	51	·8921	633·7244	8	846·2756	·1079	52
663·1730	·7979	52	52	·8869	639·6165	9	900·3835	·1131	52
716·9709	·8032	53	52	·8817	645·5034	30	34954·4966	·1183	52
770·7741	·8086	54	52	·8765	651·3851	1	35008·6149	·1235	51
824·5827	·8139	53	51	·8714	657·2616	2	062·7384	·1286	53
878·3966	·8192	53	53	·8661	663·1330	3	116·8670	·1339	51
932·2158	·8245	53	51	·8610	668·9991	4	171·0009	·1390	53
31986·0403	·8298	53	53	·8557	674·8601	35	225·1399	·1443	51
32039·8701	·8350	52	51	·8506	680·7158	6	279·2842	·1494	52
093·7051	·8404	54	52	·8454	686·5664	7	333·4336	·1546	51
147·5455	·8457	53	51	·8403	692·4118	8	387·5882	·1597	52
201·3912	·8510	53	52	·8351	698·2521	9	441·7479	·1649	52
255·2422	·8563	53	52	·8299	704·0872	40	495·9128	·1701	52
309·0985	·8615	52	52	·8247	709·9171	1	550·0829	·1753	52
362·9600	·8669	54	51	·8196	715·7418	2	604·2582	·1804	51
416·8269	·8721	52	52	·8144	721·5614	3	658·4386	·1856	52
470·6990	·8774	53	52	·8092	727·3758	4	712·6242	·1908	52
524·5764	·8827	53	51	·8041	733·1850	45	766·8150	·1959	51
578·4591	·8880	53	52	·7989	738·9891	6	821·0109	·2011	52
632·3471	·8933	53	51	·7938	744·7880	7	875·2120	·2062	51
686·2404	·8985	52	52	·7886	750·5818	8	929·4182	·2114	52
740·1389	·9038	53	51	·7835	756·3704	9	35983·6296	·2165	51
794·0427	·9091	53	52	·7783	762·1539	50	36037·8461	·2217	52
847·9518	·9143	52	52	·7731	767·9322	1	092·0678	·2269	52
901·8661	·9196	53	51	·7680	773·7053	2	146·2947	·2320	51
32955·7857	·9249	53	51	·7629	779·4733	3	200·5267	·2371	51
33009·7106	·9302	53	51	·7578	785·2362	4	254·7638	·2422	51
063·6408	·9354	52	52	·7526	790·9940	55	309·0060	·2474	52
117·5762	·9407	53	52	·7474	796·7466	6	363·2534	·2526	52
171·5169	·9459	52	51	·7423	802·4940	7	417·5060	·2577	51
225·4628	·9512	53	51	·7372	808·2363	8	471·7637	·2628	51
279·4140	53·9564	52	51	5·7321	813·9735	9	526·0265	54·2679	51
33333·3704					157819·7056	60	36580·2944		

Δ°.	Diff.	54°.	′	−54°.	Diff.	Δ°.	Δ°.	Diff.	55°.
	″	″		″				″	″
52		157819·7056	0	36580·2944			49		158154·3162
	5·7269				54·2731	52		5·4230	
51		825·4325	1	634·5675		51	51		159·7392
	·7218				·2782			·4179	
51		831·1543	2	688·8457		51	49		165·1571
	·7167				·2833			·4130	
52		836·8710	3	743·1290		52	51		170·5701
	·7115				·2885			·4079	
50		842·5825	4	797·4175		50	50		175·9780
	·7065				·2935			·4029	
52		848·2890	5	851·7110		52	49		181·3809
	·7013				·2987			·3980	
51		853·9903	6	906·0097		51	51		186·7789
	·6962				·3038			·3929	
52		859·6865	7	36960·3135		52	49		192·1718
	·6910				·3090			·3880	
50		865·3775	8	37014·6225		50	51		197·5598
	·6860				·3140			·3829	
51		871·0635	9	068·9365		51	49		202·9427
	·6809				·3191			·3780	
52		876·7444	10	123·2556		52	50		208·3207
	·6757				·3243			·3730	
51		882·4201	1	177·5799		51	50		213·6937
	·6706				·3294			·3680	
50		888·0907	2	231·9093		50	49		219·0617
	·6656				·3344			·3631	
52		893·7563	3	286·2437		52	51		224·4248
	·6604				·3396			·3580	
51		899·4167	4	340·5833		51	49		229·7828
	·6553				·3447			·3531	
50		905·0720	15	394·9280		50	50		235·1359
	·6503				·3497			·3481	
52		910·7223	6	449·2777		52	50		240·4840
	·6451				·3549			·3431	
51		916·3674	7	503·6326		51	49		245·8271
	·6400				·3600			·3382	
50		922·0074	8	557·9926		50	50		251·1653
	·6350				·3650			·3332	
51		927·6424	9	612·3576		51	50		256·4985
	·6299				·3701			·3282	
52		933·2723	20	666·7277		52	49		261·8267
	·6247				·3753			·3233	
50		938·8970	1	721·1030		50	50		267·1500
	·6197				·3803			·3183	
51		944·5167	2	775·4833		51	50		272·4683
	·6146				·3854			·3133	
51		950·1313	3	829·8687		51	49		277·7816
	·6095				·3905			·3084	
50		955·7408	4	884·2592		50	50		283·0900
	·6045				·3955			·3034	
52		961·3453	25	938·6547		52	49		288·3934
	·5993				·4007			·2985	
50		966·9446	6	37993·0554		50	50		293·6919
	·5943				·4057			·2935	
51		972·5389	7	38047·4611		51	49		298·9854
	·5892				·4108			·2886	
50		978·1281	8	101·8719		50	49		304·2740
	·5842				·4158			·2837	
52		983·7123	9	156·2877		52	50		309·5577
	·5790				·4210			·2787	
50		989·2913	30	210·7087		50	50		314·8364
	·5740				·4260			·2737	
50		157994·8653	1	265·1347		50	49		320·1101
	·5690				·4310			·2688	
52		158000·4343	2	319·5657		52	49		325·3789
	·5638				·4362			·2639	
50		005·9981	3	374·0019		50	50		330·6428
	·5588				·4412			·2589	
50		011·5569	4	428·4431		50	49		335·9017
	·5538				·4462			·2540	
51		017·1107	35	482·8893		51	50		341·1557
	·5487				·4513			·2490	
51		022·6594	6	537·3406		51	48		346·4047
	·5436				·4564			·2442	
50		028·2030	7	591·7970		50	50		351·6489
	·5386				·4614			·2392	
51		033·7416	8	646·2584		51	50		356·8881
	·5335				·4665			·2342	
50		039·2751	9	700·7249		50	48		362·1223
	·5285				·4715			·2294	
50		044·8036	40	755·1964		50	50		367·3517
	·5235				·4765			·2244	
51		050·3271	1	809·6729		51	49		372·5761
	·5184				·4816			·2195	
51		055·8455	2	864·1545		51	49		377·7956
	·5133				·4867			·2146	
50		061·3588	3	918·6412		50	49		383·0102
	·5083				·4917			·2097	
50		066·8671	4	38973·1329		50	49		388·2199
	·5033				·4967			·2048	
50		072·3704	45	39027·6296		51	50		393·4247
	·4982				·5018			·1998	
50		077·8686	6	082·1314		50	48		398·6245
	·4932				·5068			·1950	
50		083·3618	7	136·6382		50	50		403·8195
	·4882				·5118			·1900	
51		088·8500	8	191·1500		51	49		409·0095
	·4831				·5169			·1851	
50		094·3331	9	245·6669		50	48		414·1946
	·4781				·5219			·1803	
50		099·8112	50	300·1888		50	50		419·3749
	·4731				·5269			·1753	
50		105·2843	1	354·7157		50	49		424·5502
	·4681				·5319			·1704	
51		110·7524	2	409·2476		51	48		429·7206
	·4630				·5370			·1656	
50		116·2154	3	463·7846		50	50		434·8862
	·4580				·5420			·1606	
50		121·6734	4	518·3266		50	49		440·0468
	·4530				·5470			·1557	
50		127·1264	55	572·8736		50	48		445·2025
	·4480				·5520			·1509	
50		132·5744	6	627·4256		50	50		450·3534
	·4430				·5570			·1459	
50		138·0174	7	681·9826		50	48		455·4993
	·4380				·5620			·1411	
51		143·4554	8	736·5446		51	49		460·6404
	·4329				·5671			·1362	
50		148·8883	9	791·1117		50	49		465·7766
	5·4279	158154·3162	60	39845·6838	54·5721			5·1313	158470·9079

−55°.	Diff.	Δ².	Δ².	Diff.	56°.	′	−56°.	Diff.	Δ².
″	″			″	″		″	″	
39845·6838		49	48		158470·9079	0	43129·0921		48
900·2608	54·5770	51	50	5·1265	476·0344	1	183·9656	54·8735	50
39954·8429	·5821	49	48	·1215	481·1559	2	238·8441	·8785	48
40009·4299	·5870	51	49	·1167	486·2726	3	293·7274	·8833	49
064·0220	·5921	50	48	·1118	491·3844	4	348·6156	·8882	48
118·6191	·5971	49	50	·1070	496·4914	5	403·5086	·8930	50
173·2211	·6020	51	48	·1020	501·5934	6	458·4066	·8980	48
227·8282	·6071	49	49	·0972	506·6906	7	513·3094	·9028	49
282·4402	·6120	51	48	·0923	511·7829	8	568·2171	·9077	48
337·0573	·6171	49	49	·0875	516·8704	9	623·1296	·9125	49
	·6220			·0826				·9174	
391·6793		50	48		521·9530	10	678·0470		48
446·3063	·6270	50	49	·0778	527·0308	1	732·9692	·9222	49
500·9383	·6320	49	49	·0729	532·1037	2	787·8963	·9271	49
555·5752	·6369	51	48	·0680	537·1717	3	842·8283	·9320	48
610·2172	·6420	49	49	·0632	542·2349	4	897·7651	·9368	49
664·8641	·6469	50	48	·0583	547·2932	15	43952·7068	·9417	48
719·5160	·6519	50	48	·0535	552·3467	6	44007·6533	·6465	48
774·1729	·6569	49	49	·0487	557·3954	7	062·6046	·9513	49
828·8347	·6618	50	49	·0438	562·4392	8	117·5608	·9562	49
883·5015	·6668	50	48	·0389	567·4781	9	172·5219	·9611	48
	·6718			·0341				·9659	
938·1733		49	48		572·5122	20	227·4878		48
40992·8500	·6767	50	48	·0293	577·5415	1	282·4585	·9707	48
41047·5317	·6817	50	49	·0245	582·5660	2	337·4340	·9755	49
102·2184	·6867	49	49	·0196	587·5856	3	392·4144	·9804	49
156·9100	·6916	50	47	·0147	592·6003	4	447·3997	·9853	47
211·6066	·6966	49	49	·0100	597·6103	25	502·3897	·9900	49
266·3081	·7015	50	48	·0051	602·6154	6	557·3846	·9949	49
321·0146	·7065	49	48	5·0003	607·6157	7	612·3843	54·9997	48
375·7260	·7114	49	49	4·9955	612·6112	8	667·3888	55·0045	48
430·4423	·7163	50	47	·9906	617·6018	9	722·3982	·0094	49
	·7213			·9859				·0141	47
485·1636		50	49	·9810	622·5877	30	777·4123		49
539·8899	·7263	49	48	·9762	627·5687	1	832·4313	·0190	48
594·6211	·7312	49	48	·9714	632·5449	2	887·4551	·0238	48
649·3572	·7361	50	49	·9665	637·5163	3	942·4837	·0286	49
704·0983	·7411	49	47	·9618	642·4828	4	44997·5172	·0335	47
758·8443	·7460	50	48	·9570	647·4446	35	45052·5554	·0382	48
813·5953	·7510	48	48	·9522	652·4016	6	107·5984	·0430	48
868·3511	·7558	50	49	·9473	657·3538	7	162·6462	·0478	49
923·1119	·7608	50	47	·9426	662·3011	8	217·6989	·0527	47
41977·8777	·7658	48	49	·9377	667·2437	9	272·7563	·0574	49
	·7706							·0623	
42032·6483		50	47	·9330	672·1814	40	327·8186		47
087·4239	·7756	49	48	·9282	677·1144	1	382·8856	·0670	48
142·2044	·7805	49	48	·9234	682·0426	2	437·9574	·0718	48
196·9898	·7854	49	48	·9186	686·9660	3	493·0340	·0766	48
251·7801	·7903	49	48	·9138	691·8846	4	548·1154	·0814	48
306·5753	·7952	50	48	·9090	696·7984	45	603·2016	·0862	48
361·3755	·8002	48	48	·9042	701·7074	6	658·2926	·0910	48
416·1805	·8050	50	47	·8995	706·6116	7	713·3884	·0958	48
470·9905	·8100	49	48	·8947	711·5111	8	768·4889	·1005	47
525·8054	·8149	48	48	·8899	716·4058	9	823·5942	·1053	48
	·8197							·1101	48
580·6251		50	48	·8851	721·2957	50	878·7043		48
635·4498	·8247	49	47	·8804	726·1808	1	933·8192	·1149	47
690·2794	·8296	48	48	·8756	731·0612	2	45988·9388	·1196	48
745·1138	·8344	50	48	·8708	735·9368	3	46044·0632	·1244	48
799·9532	·8394	49	48	·8660	740·8076	4	099·1924	·1292	48
854·7975	·8443	48	47	·8613	745·6736	55	154·3264	·1340	48
909·6466	·8491	50	47	·8566	750·5349	6	209·4651	·1387	47
42964·5007	·8541	48	48	·8518	755·3915	7	264·6085	·1434	47
43019·3596	·8589	49	48	·8470	760·2433	8	319·7567	·1482	48
074·2234	·8638	49	48		765·0903	9	374·9097	·1530	48
43129·0921	54·8687			4·8422	158769·9325	60	46430·0675	55·1578	

Δ°.	Diff.	57°.	′	−57°.	Diff.	Δ°.	Δ°.	Diff.	58°.
	″	″		″	″			″	″
47	4·8375	158769·9325	0	46430·0675	55·1625	47	47	4·5562	159051·8472
47	·8328	774·7700	1	485·2300	·1672	47	46	·5516	056·4034
48	·8280	779·6028	2	540·3972	·1720	48	46	·5470	060·9550
48	·8232	784·4308	3	595·5692	·1768	48	46	·5424	065·5020
47	·8185	789·2540	4	650·7460	·1815	47	46	·5378	070·0444
47	·8138	794·0725	5	705·9275	·1862	47	46	·5332	074·5822
47	·8091	798·8863	6	761·1137	·1909	47	47	·5285	079·1154
48	·8043	803·6954	7	816·3046	·1957	48	46	·5239	083·6439
48	·7995	808·4997	8	871·5003	·2005	48	45	·5194	088·1678
46	·7949	813·2992	9	926·7008	·2051	46	47	·5147	092·6872
48	·7901	818·0941	10	46981·9059	·2099	48	46	·5101	097·2019
48	·7853	822·8842	1	47037·1158	·2147	48	46	·5055	101·7120
47	·7806	827·6695	2	092·3305	·2194	47	46	·5009	106·2175
46	·7760	832·4501	3	147·5499	·2240	46	45	·4964	110·7184
48	·7712	837·2261	4	202·7739	·2288	48	47	·4917	115·2148
48	·7664	841·9973	15	258·0027	·2336	48	46	·4871	119·7065
46	·7618	846·7637	6	313·2363	·2382	46	45	·4826	124·1936
48	·7570	851·5255	7	368·4745	·2430	48	47	·4779	128·6762
47	·7523	856·2825	8	423·7175	·2477	47	45	·4734	133·1541
47	·7476	861·0348	9	478·9652	·2524	47	46	·4688	137·6275
47	·7429	865·7824	20	534·2176	·2571	47	46	·4642	142·0963
47	·7382	870·5253	1	589·4747	·2618	47	46	·4596	146·5605
47	·7335	875·2635	2	644·7365	·2665	47	45	·4551	151·0201
47	·7288	879·9970	3	700·0030	·2712	47	46	·4505	155·4752
47	·7241	884·7258	4	755·2742	·2759	47	46	·4459	159·9257
48	·7193	889·4499	25	810·5501	·2807	48	46	·4413	164·3716
46	·7147	894·1692	6	865·8308	·2853	46	45	·4368	168·8129
47	·7100	898·8839	7	921·1161	·2900	47	46	·4322	173·2497
47	·7053	903·5939	8	47976·4061	·2947	47	46	·4276	177·6819
47	·7006	908·2992	9	48031·7008	·2994	47	45	·4231	182·1095
47	·6959	912·9998	30	087·0002	·3041	47	46	·4185	186·5326
47	·6912	917·6957	1	142·3043	·3088	47	45	·4140	190·9511
46	·6866	922·3869	2	197·6131	·3134	46	46	·4094	195·3651
48	·6818	927·0735	3	252·9265	·3182	48	46	·4048	199·7745
46	·6772	931·7553	4	308·2447	·3228	46	45	·4003	204·1793
47	·6725	936·4325	35	363·5675	·3275	47	45	·3958	208·5796
46	·6679	941·1050	6	418·8950	·3321	46	46	·3912	212·9754
48	·6631	945·7729	7	474·2271	·3369	48	46	·3866	217·3666
46	·6585	950·4360	8	529·5640	·3415	46	45	·3821	221·7532
47	·6538	955·0945	9	584·9055	·3462	47	45	·3776	226·1353
47	·6491	959·7483	40	640·2517	·3509	47	45	·3731	230·5129
46	·6445	964·3974	1	695·6026	·3555	46	46	·3685	234·8860
47	·6398	969·0419	2	750·9581	·3602	47	46	·3639	239·2545
46	·6352	973·6817	3	806·3183	·3648	46	44	·3595	243·6184
47	·6305	978·3169	4	861·6831	·3695	47	46	·3549	247·9779
47	·6258	982·9474	45	917·0526	·3742	47	45	·3504	252·3328
46	·6212	987·5732	6	48972·4268	·3788	46	46	·3458	256·6832
47	·6165	992·1944	7	49027·8056	·3835	47	44	·3414	261·0290
46	·6119	158996·8109	8	083·1891	·3881	46	46	·3368	265·3704
47	·6072	159001·4228	9	138·5772	·3928	47	45	·3323	269·7072
46	·6026	006·0300	50	193·9700	·3974	46	46	·3277	274·0395
46	·5980	010·6326	1	249·3674	·4020	46	44	·3233	278·3672
47	·5933	015·2306	2	304·7694	·4067	47	45	·3188	282·6905
47	·5886	019·8239	3	360·1761	·4114	47	46	·3142	287·0093
46	·5840	024·4125	4	415·5875	·4160	46	45	·3097	291·3235
46	·5794	028·9965	55	471·0035	·4206	46	45	·3052	295·6332
46	·5748	033·5759	6	526·4241	·4252	46	44	·3008	299·9384
47	·5701	038·1507	7	581·8493	·4299	47	46	·2962	304·2392
46	·5655	042·7208	8	637·2792	·4345	46	45	·2917	308·5354
46	·5609	047·2863	9	692·7137			44	·2873	312·8271
	4·5609	159051·8472	60	49748·1528	55·4391			4·2873	159317·1144

−58°.	Diff.	Δ¹.	Δ².	Diff.	59°.	′	−59°	Diff.	Δ¹.
49748·1528	55·4438	47	46	4·2827	159317·1144	0	53082·8856	55·7173	46
803·5966	·4484	46	45	·2782	321·3971	1	138·6029	·7218	45
859·0450	·4530	46	44	·2738	325·6753	2	194·3247	·7262	44
914·4980	·4576	46	46	·2692	329·9491	3	250·0509	·7308	46
49969·9556	·4622	46	44	·2648	334·2183	4	305·7817	·7352	44
50025·4178	·4668	46	45	·2603	338·4831	5	361·5169	·7397	45
080·8846	·4715	47	45	·2558	342·7434	6	417·2566	·7442	45
136·3561	·4761	46	44	·2514	346·9992	7	473·0008	·7486	44
191·8322	·4806	45	46	·2468	351·2506	8	528·7494	·7532	46
247·3128	·4853	47	44	·2424	355·4974	9	584·5026	·7576	44
302·7981	·4899	46	45	·2379	359·7398	10	640·2602	·7621	45
358·2880	·4945	46	44	·2335	363·9777	1	696·0223	·7665	44
413·7825	·4991	46	46	·2289	368·2112	2	751·7888	·7711	46
469·2816	·5036	45	44	·2245	372·4401	3	807·5599	·7755	44
524·7852	·5083	47	44	·2201	376·6646	4	863·3354	·7799	44
580·2935	·5129	46	45	·2156	380·8847	15	919·1153	·7844	45
635·8064	·5174	45	45	·2111	385·1003	6	53974·8997	·7889	45
691·3238	·5221	47	45	·2066	389·3114	7	54030·6886	·7934	45
746·8459	·5266	45	44	·2022	393·5180	8	086·4820	·7978	44
802·3725	·5312	46	44	·1978	397·7202	9	142·2798	·8022	44
857·9037	·5358	46	45	·1933	401·9180	20	198·0820	·8067	45
913·4395	·5404	46	45	·1888	406·1113	1	253·8887	·8112	45
50968·9799	·5449	45	44	·1844	410·3001	2	309·6999	·8156	44
51024·5248	·5495	46	44	·1800	414·4845	3	365·5155	·8200	44
080·0743	·5541	46	45	·1755	418·6645	4	421·3355	·8245	45
135·6284	·5587	46	44	·1711	422·8400	25	477·1600	·8289	44
191·1871	·5632	45	45	·1666	427·0111	6	532·9889	·8334	45
246·7503	·5678	46	44	·1622	431·1777	7	588·8223	·8378	44
302·3181	·5724	46	44	·1578	435·3399	8	644·6601	·8422	44
357·8905	·5769	45	45	·1533	439·4977	9	700·5023	·8467	45
413·4674	·5815	46	44	·1489	443·6510	30	756·3490	·8511	44
469·0489	·5860	45	44	·1445	447·7999	1	812·2001	·8555	44
524·6349	·5906	46	44	·1401	451·9444	2	868·0556	·8599	44
580·2255	·5952	46	45	·1356	456·0845	3	923·9155	·8644	45
635·8207	·5997	45	43	·1313	460·2201	4	54979·7799	·8687	43
691·4204	·6042	45	45	·1268	464·3514	35	55035·6486	·8732	45
747·0246	·6088	46	45	·1223	468·4782	6	091·5218	·8777	45
802·6334	·6134	46	43	·1180	472·6005	7	147·3995	·8820	43
858·2468	·6179	45	44	·1136	476·7185	8	203·2815	·8864	44
913·8647	·6224	45	45	·1091	480·8321	9	259·1679	·8909	45
51969·4871	·6269	45	44	·1047	484·9412	40	315·0588	·8953	44
52025·1140	·6315	46	43	·1004	489·0459	1	370·9541	·8996	43
080·7455	·6361	46	45	·0959	493·1463	2	426·8537	·9041	45
136·3816	·6405	44	43	·0916	497·2422	3	482·7578	·9084	43
192·0221	·6451	46	45	·0871	501·3338	4	538·6662	·9129	45
247·6672	·6496	45	44	·0827	505·4209	45	594·5791	·9173	44
303·3168	·6542	46	43	·0784	509·5036	6	650·4964	·9216	43
358·9710	·6586	44	45	·0739	513·5820	7	706·4180	·9261	45
414·6296	·6632	46	44	·0695	517·6559	8	762·3441	·9305	44
470·2928	·6677	45	43	·0652	521·7254	9	818·2746	·9348	43
525·9605	·6723	46	44	·0608	525·7906	50	874·2094	·9392	44
581·6328	·6767	44	44	·0564	529·8514	1	930·1486	·9436	44
637·3095	·6812	45	43	·0521	533·9078	2	55986·0922	·9479	43
692·9907	·6858	46	45	·0476	537·9599	3	56042·0401	·9524	45
748·6765	·6903	45	43	·0433	542·0075	4	097·9925	·9567	43
804·3668	·6948	45	44	·0389	546·0508	55	153·9492	·9611	44
860·0616	·6992	44	44	·0345	550·0897	6	209·9103	·9655	44
915·7608	·7038	46	44	·0301	554·1242	7	265·8758	·9699	44
52971·4646	·7083	45	43	·0258	558·1543	8	321·8457	·9742	43
53027·1729		44	43		562·1801	9	377·8199		43
53082·8856	55·7127			4·0215	159566·2016	60	56433·7984	55·9785	

Δ°.	Diff.	60°.	′	−60°.	Diff.	Δ°.	Δ°.	Diff.	61°.
	″	″		″	″			″	″
45	4·0170	159566·2016	0	56433·7984	55·9830	45	42	3·7593	159799·5812
43	·0127	570·2186	1	489·7814	·9873	43	43	·7550	803·3405
44	·0083	574·2313	2	545·7687	·9917	44	41	·7509	807·0955
43	4·0040	578·2396	3	601·7604	55·9960	43	43	·7466	810·8464
43	3·9997	582·2436	4	657·7564	56·0003	43	42	·7424	814·5930
45	·9952	586·2433	5	713·7567	·0048	45	42	·7382	818·3354
43	·9909	590·2385	6	769·7615	·0091	43	43	·7339	822·0736
43	·9866	594·2294	7	825·7706	·0134	43	41	·7298	825·8075
44	·9822	598·2160	8	881·7840	·0178	44	43	·7255	829·5373
43	·9779	602·1982	9	937·8018	·0221	43	42	·7213	833·2628
43	·9736	606·1761	10	56993·8239	·0264	43	42	·7171	836·9841
44	·9692	610·1497	1	57049·8503	·0308	44	42	·7129	840·7012
44	·9648	614·1189	2	105·8811	·0352	44	42	·7087	844·4141
42	·9606	618·0837	3	161·9163	·0394	42	42	·7045	848·1228
44	·9562	622·0443	4	217·9557	·0438	44	42	·7003	851·8273
43	·9519	626·0005	15	273·9995	·0481	43	42	·6961	855·5276
44	·9475	629·9524	6	330·0476	·0525	44	42	·6919	859·2237
43	·9432	633·8999	7	386·1001	·0568	43	42	·6877	862·9156
43	·9389	637·8431	8	442·1569	·0611	43	42	·6835	866·6033
43	·9346	641·7820	9	498·2180	·0654	43	41	·6794	870·2868
44	·9302	645·7166	20	554·2834	·0698	44	43	·6751	873·9662
42	·9260	649·6468	1	610·3532	·0740	42	41	·6710	877·6413
44	·9216	653·5728	2	666·4272	·0784	44	42	·6668	881·3123
43	·9173	657·4944	3	722·5056	·0827	43	42	·6626	884·9791
43	·9130	661·4117	4	778·5883	·0870	43	42	·6584	888·6417
43	·9087	665·3247	25	834·6753	·0913	43	42	·6542	892·3001
43	·9044	669·2334	6	890·7666	·0956	43	41	·6501	895·9543
43	·9001	673·1378	7	57946·8622	·0999	43	42	·6459	899·6044
44	·8957	677·0379	8	58002·9621	·1043	44	42	·6417	903·2503
42	·8915	680·9336	9	059·0664	·1085	42	41	·6376	906·8920
43	·8872	684·8251	30	115·1749	·1128	43	42	·6334	910·5296
43	·8829	688·7123	1	171·2877	·1171	43	41	·6293	914·1630
43	·8786	692·5952	2	227·4048	·1214	43	42	·6251	917·7923
43	·8743	696·4738	3	283·5262	·1257	43	42	·6209	921·4174
43	·8700	700·3481	4	339·6519	·1300	43	42	·6167	925·0383
43	·8657	704·2181	35	395·7819	·1343	43	41	·6126	928·6550
42	·8615	708·0838	6	451·9162	·1385	42	41	·6085	932·2676
44	·8571	711·9453	7	508·0547	·1429	44	42	·6043	935·8761
42	·8529	715·8024	8	564·1976	·1471	42	41	·6002	939·4804
43	·8486	719·6553	9	620·3447	·1514	43	41	·5961	943·0806
43	·8443	723·5039	40	676·4961	·1557	43	42	·5919	946·6767
42	·8401	727·3482	1	732·6518	·1599	42	42	·5877	950·2686
43	·8358	731·1883	2	788·8117	·1642	43	41	·5836	953·8563
43	·8315	735·0241	3	844·9759	·1685	43	41	·5795	957·4399
43	·8272	738·8556	4	901·1444	·1728	43	42	·5753	961·0194
42	·8230	742·6828	45	58957·3172	·1770	42	41	·5712	964·5947
42	·8188	746·5058	6	59013·4942	·1812	42	41	·5671	968·1659
44	·8144	750·3246	7	069·6754	·1856	44	41	·5630	971·7330
42	·8102	754·1390	8	125·8610	·1898	42	42	·5588	975·2960
42	·8060	757·9492	9	182·0508	·1940	42	41	·5547	978·8548
43	·8017	761·7552	50	238·2448	·1983	43	41	·5506	982·4095
43	·7974	765·5569	1	294·4431	·2026	43	41	·5465	985·9601
42	·7932	769·3543	2	350·6457	·2068	42	41	·5424	989·5066
42	·7890	773·1475	3	406·8525	·2110	42	42	·5382	993·0490
43	·7847	776·9365	4	463·0635	·2153	43	41	·5341	159996·5872
42	·7805	780·7212	55	519·2788	·2195	42	40	·5301	160000·1213
43	·7762	784·5017	6	575·4983	·2238	43	42	·5259	003·6514
42	·7720	788·2779	7	631·7221	·2280	42	41	·5218	007·1773
42	·7678	792·0499	8	687·9501	·2322	42	41	·5177	010·6991
43	·7635	795·8177	9	744·1823	56·2365	43	40	·5137	014·2168
	3·7635	159799·5812	60	59800·4188				3·5137	160017·7305

′	−61°.	Diff.	Δ².	Δ³.	Diff.	62°.	′	−62°.	Diff.	Δ².
	″	″			″	″		″	″	
0	59800·4188			42		160017·7305.	0	63182·2695		
		56·2407	42		3·5095				56·4905	42
1	856·6595		43	41		021·2400	1	238·7600		41
		·2450			·5054				·4946	
2	912·9045.		41	40		024·7454	2	295·2546		40
		·2491			·5014				·4986	
3	59969·1536		43	42		028·2468	3	351·7532		42
		·2534			·4972				·5028	
4	60025·4070		42	40		031·7440	4	408·2560		40
		·2576			·4932				·5068	
5	081·6646		42	42		035·2372	5	464·7628		42
		·2618			·4890				·5110	
6	137·9264		43	40		038·7262	6	521·2738		40
		·2661			·4850				·5150	
7	194·1925.		41	41		042·2112	7	577·7888		41
		·2702			·4809				·5191	
8	250·4627		43	40		045·6921	8	634·3079		40
		·2745			·4769				·5231	
9	306·7372		42	42		049·1690	9	690·8310		42
		·2787			·4727				·5273	
0	363·0159					052·6417	10	747·3583		
		·2829	42	40					·5313	40
1	419·2988		42	41	·4687	056·1104	1	803·8896		41
		·2871			·4646				·5354	
2	475·5859		42	41		059·5750.	2	860·4250		41
		·2913			·4605				·5395	
3	531·8772		42	40		063·0355	3	916·9645.		40
		·2955			·4565				·5435	
4	588·1727		42	41		066·4920	4	63973·5080		41
		·2997			·4524				·5476	
5	644·4724		42	41		069·9444	15	64030·0556		41
		·3039			·4483				·5517	
6	700·7763		42	40		073·3927	6	086·6073		40
		·3081			·4443				·5557	
7	757·0844		42	41		076·8370	7	143·1630		41
		·3123			·4402				·5598	
8	813·3967		42	40		080·2772	8	199·7228		40
		·3165			·4362				·5638	
9	869·7132		41	41		083·7134	9	256·2866		41
		·3206			·4321				·5679	
10	926·0338					087·1455	20	312·8545.		
		·3249	43	40					·5719	40
1	60982·3587		41	41	·4281	090·5736	1	369·4264		41
		·3290			·4240				·5760	
2	61038·6877		42	41		093·9976	2	426·0024		41
		·3332			·4199				·5801	
3	095·0209		42	40		097·4175	3	482·5825.		40
		·3374			·4159				·5841	
4	151·3583		42	40		100·8334	4	539·1666		40
		·3416			·4119				·5881	
15	207·6999		42	40		104·2453	25	595·7547		40
		·3458			·4079				·5921	
6	264·0457		41	41		107·6532	6	652·3468		41
		·3499			·4038				·5962	
7	320·3956		42	41		111·0570	7	708·9430		41
		·3541			·3997				·6003	
8	376·7497		42	40		114·4567	8	765·5433		40
		·3583			·3957				·6043	
9	433·1080		41	40		117·8524	9	822·1476		40
		·3624			·3917				·6083	
30	489·4704					121·2441	30	878·7559		
		·3666	42	40	·3877				·6123	40
1	545·8370		41	41		124·6318	1	935·3682		41
		·3707			·3836				·6164	
2	602·2077		42	40		128·0154	2	64991·9846		40
		·3749			·3796				·6204	
3	658·5826		42	40		131·3950	3	65048·6050.		40
		·3791			·3756				·6244	
4	714·9617		42	40		134·7706	4	105·2294		40
		·3833			·3716				·6284	
35	771·3450.		41	41		138·1422	35	161·8578		41
		·3874			·3675				·6325	
6	827·7324		41	39		141·5097	6	218·4903		39
		·3915			·3636				·6364	
7	884·1239		42	41		144·8733	7	275·1267		41
		·3957			·3595				·6405	
8	940·5196		41	40		148·2328	8	331·7672		40
		·3998			·3555				·6445	
9	61996·9194		41	40		151·5883	9	388·4117		40
		·4039			·3515				·6485	
40	62053·3233					154·9398	40	445·0602		
		·4081	42	40	·3475				·6525	40
1	109·7314		42	41		158·2873	1	501·7127		41
		·4123			·3434				·6566	
2	166·1437		41	39		161·6307	2	558·3693		39
		·4164			·3395				·6605	
3	222·5601		41	40		164·9702	3	615·0298		40
		·4205			·3355				·6645	
4	278·9806		42	40		168·3057	4	671·6943		40
		·4247			·3315				·6685	
45	335·4053		41	40		171·6372	45	728·3628		40
		·4288			·3275				·6725	
6	391·8341		41	40		174·9647	6	785·0353		40
		·4329			·3235				·6765	
7	448·2670		41	40		178·2882	7	841·7118		40
		·4370			·3195				·6805	
8	504·7040		42	40		181·6077	8	898·3923		40
		·4412			·3155				·6845	
9	561·1452		41	40		184·9232	9	65955·0768		40
		·4453			·3115				·6885	
50	617·5905.					188·2347	50	66011·7653		
		·4494	41	39	·3076				·6924	39
1	674·0399		41	41		191·5423	1	068·4577		41
		·4535			·3035				·6965	
2	730·4934		41	39		194·8458	2	125·1542		39
		·4576			·2996				·7004	
3	786·9510		42	40		198·1454	3	181·8546		40
		·4618			·2956				·7044	
4	843·4128		41	40		201·4410	4	238·5590		40
		·4659			·2916				·7084	
55	899·8787		40	39		204·7326	55	295·2674		39
		·4699			·2877				·7123	
6	62956·3486		42	40		208·0203	6	351·9797		40
		·4741			·2837				·7163	
7	63012·8227		41	40		211·3040	7	408·6960		40
		·4782			·2797				·7203	
8	069·3009		41	39		214·5837	8	465·4163		39
		·4823			·2758				·7242	
9	125·7832		40	41		217·8595.	9	522·1405		41
		56·4863			3·2717				56·7283	
60	63182·2695					160221·1312	60	66578·8688		

Δ°.	Diff.	63°.		−63°.	Diff.	Δ°.	Δ°.	Diff.	64°.
	″	″		″	″			″	″
39	3·2678	160221·1312	0	66578·8688	56·7322	39	38	3·0343	160410·2698
39	·2639	224·3990	1	635·6010	·7361	39	39	·0304	413·3041
40	·2599	227·6629	2	692·3371	·7401	40	37	·0267	416·3345
39	·2560	230·9228	3	749·0772	·7440	39	39	·0228	419·3612
40	·2520	234·1788	4	805·8212	·7480	40	38	·0190	422·3840
40	·2480	237·4308	5	862·5692	·7520	40	39	·0151	425·4030
39	·2441	240·6788	6	919·3212	·7559	39	37	·0114	428·4181
39	·2402	243·9229	7	66976·0771	·7598	39	39	·0075	431·4295
40	·2362	247·1631	8	67032·8369	·7638	40	37	3·0038	434·4370
39	·2323	250·3993	9	089·6007	·7677	39	39	2·9999	437·4408
40	·2283	253·6316	10	146·3684	·7717	40	37	·9962	440·4407
39	·2244	256·8599	1	203·1401	·7756	39	39	·9923	443·4369
40	·2204	260·0843	2	259·9157	·7796	40	38	·9885	446·4292
38	·2166	263·3047	3	316·6953	·7834	38	37	·9848	449·4177
40	·2126	266·5213	4	373·4787	·7874	40	39	·9809	452·4025
40	·2086	269·7339	15	430·2661	·7914	40	37	·9772	455·3834
38	·2048	272·9425	6	487·0575	·7952	38	38	·9734	458·3606
40	·2008	276·1473	7	543·8527	·7992	40	39	·9695	461·3340
39	·1969	279·3481	8	600·6519	·8031	39	37	·9658	464·3035
39	·1930	282·5450	9	657·4550	·8070	39	38	·9620	467·2693
40	·1890	285·7380	20	714·2620	·8110	40	37	·9583	470·2313
38	·1852	288·9270	1	771·0730	·8148	38	39	·9544	473·1896
40	·1812	292·1122	2	827·8878	·8188	40	37	·9507	476·1440
38	·1774	295·2934	3	884·7066	·8226	38	38	·9469	479·0947
40	·1734	298·4708	4	941·5292	·8266	40	37	·9432	482·0416
39	·1695	301·6442	25	67998·3558	·8305	39	39	·9393	484·9848
39	·1656	304·8137	6	68055·1863	·8344	39	37	·9356	487·9241
39	·1617	307·9793	7	112·0207	·8383	39	37	·9319	490·8597
39	·1578	311·1410	8	168·8590	·8422	39	38	·9281	493·7916
39	·1539	314·2988	9	225·7012	·8461	39	38	·9243	496·7197
39	·1500	317·4527	30	282·5473	·8500	39	38	·9205	499·6440
38	·1462	320·6027	1	339·3973	·8538	38	37	·9168	502·5645
40	·1422	323·7489	2	396·2511	·8578	40	37	·9131	505·4813
38	·1384	326·8911	3	453·1089	·8616	38	38	·9093	508·3944
39	·1345	330·0295	4	509·9705	·8655	39	37	·9056	511·3037
40	·1305	333·1640	35	566·8360	·8695	40	38	·9018	514·2093
38	·1267	336·2945	6	623·7055	·8733	38	37	·8981	517·1111
38	·1229	339·4212	7	680·5788	·8771	38	38	·8943	520·0092
40	·1189	342·5441	8	737·4559	·8811	40	37	·8906	522·9035
38	·1151	345·6630	9	794·3370	·8849	38	38	·8868	525·7941
39	·1112	348·7781	40	851·2219	·8888	39	36	·8832	528·6809
38	·1074	351·8893	1	908·1107	·8926	38	38	·8794	531·5641
40	·1034	354·9967	2	68965·0033	·8966	40	38	·8756	534·4435
38	·0996	358·1001	3	69021·8999	·9004	38	37	·8719	537·3191
38	·0958	361·1997	4	078·8003	·9042	38	37	·8682	540·1910
39	·0919	364·2955	45	135·7045	·9081	39	37	·8645	543·0592
39	·0880	367·3874	6	192·6126	·9120	39	37	·8608	545·9237
38	·0842	370·4754	7	249·5246	·9158	38	38	·8570	548·7845
39	·0803	373·5596	8	306·4404	·9197	39	36	·8534	551·6415
38	·0765	376·6399	9	363·3601	·9235	38	38	·8496	554·4949
39	·0726	379·7164	50	420·2836	·9274	39	37	·8459	557·3445
38	·0688	382·7890	1	477·2110	·9312	38	37	·8422	560·1904
39	·0649	385·8578	2	534·1422	·9351	39	37	·8385	563·0326
38	·0611	388·9227	3	591·0773	·9389	38	37	·8348	565·8711
38	·0573	391·9838	4	648·0162	·9427	38	37	·8311	568·7059
39	·0534	395·0411	55	704·9589	·9466	39	38	·8273	571·5370
38	·0496	398·0945	6	761·9055	·9504	38	36	·8237	574·3643
39	·0457	401·1441	7	818·8559	·9543	39	37	·8200	577·1880
38	·0419	404·1898	8	875·8102	·9581	38	37	·8163	580·0080
38	·0381	407·2317	9	932·7683	56·9619	38	37	·8126	582·8243
	3·0381	160410·2698	60	69989·7302				2·8126	160585·6369

′	−64°.	Diff.	Δ².	Δ².	Diff.	65°.	′	.−65°.	Diff.	Δ².
	″	″			″	″		″	″	
0	69989·7302		38	36		160585·6369	0	73414·3631		36
		56·9657			2·8090				57·1910	
1	70046·6959		39	38	·8052	588·4459	1	471·5541	·1948	38
		·9696		36		591·2511		528·7489		36
2	103·6655		37		·8016		2		·1984	
		·9733		38		594·0527		585·9473		38
3	160·6388		39		·7978		3		·2022	
		·9772		36		596·8505		643·1495		36
4	217·6160		38		·7942		4		·2058	
		·9810		37		599·6447		700·3553		37
5	274·5970		39		·7905		5		·2095	
		·9849		36		602·4352		757·5648		36
6	331·5819		37		·7869		6		·2131	
		·9886		38		605·2221		814·7779		38
7	388·5705		39		·7831		7		·2169	
		·9925		36		608·0052		871·9948		36
8	445·5630		37		·7795		8		·2205	
		56·9962		36		610·7847		929·2153		36
9	502·5592	57·0001	39		·7759		9		·2241	
10	559·5593		37	37	·7722	613·5606	10	73986·4394	·2278	37
		·0038								
1	616·5631		39	37	·7685	616·3328	1	74043·6672	·2315	37
		·0077								
2	673·5708		38	37	·7648	619·1013	2	100·8987	·2352	37
		·0115								
3	730·5823		37	36	·7612	621·8661	3	158·1339	·2388	36
		·0152								
4	787·5975		39	37	·7575	624·6273	4	215·3727	·2425	37
		·0191								
15	844·6166		37	36	·7539	627·3848	15	272·6152	·2461	36
		·0228								
6	901·6394		38	37	·7502	630·1387	6	329·8613	·2498	37
		·0266								
7	70958·6660		39	36	·7466	632·8889	7	387·1111	·2534	36
		·0305								
8	71015·6965		37	37	·7429	635·6355	8	444·3645	·2571	37
		·0342								
9	072·7307	·0380	38	36	·7393	638·3784	9	501·6216	·2607	36
20	129·7687		37	36		641·1177	20	558·8823		36
		·0417			·7357				·2643	
1	186·8104		39	37	·7320	643·8534	1	616·1466	·2680	37
		·0456								
2	243·8560		37	37	·7283	646·5854	2	673·4146	·2717	37
		·0493								
3	300·9053		38	35	·7248	649·3137	3	730·6863	·2752	35
		·0531								
4	357·9584		37	37	·7211	652·0385	4	787·9615	·2789	37
		·0568								
25	415·0152		39	37	·7174	654·7596	25	845·2404	·2826	37
		·0607								
6	472·0759		37	35	·7139	657·4770	6	902·5230	·2861	35
		·0644								
7	529·1403		37	37	·7102	660·1909	7	74959·8091	·2898	37
		·0681								
8	586·2084		38	36	·7066	662·9011	8	75017·0989	·2934	36
		·0719								
9	643·2803	·0757	38	36	·7030	665·6077	9	074·3923	·2970	36
30	700·3560		38	37		668·3107	30	131·6893		37
		·0795			·6993				·3007	
1	757·4355		37	35	·6958	671·0100	1	188·9900	·3042	35
		·0832								
2	814·5187		37	37	·6921	673·7058	2	246·2942	·3079	37
		·0869								
3	871·6056		38	36	·6885	676·3979	3	303·6021	·3115	36
		·0907								
4	928·6963		37	36	·6849	679·0864	4	360·9136	·3151	36
		·0944								
35	71985·7907		38	36	·6813	681·7713	35	418·2287	·3187	36
		·0982								
6	72042·8889		37	36	·6777	684·4526	6	475·5474	·3223	36
		·1019								
7	099·9908		38	36	·6741	687·1303	7	532·8697	·3259	36
		·1057								
8	157·0965		37	36	·6705	689·8044	8	590·1956	·3295	36
		·1094								
9	214·2059	·1132	38	37	·6668	692·4749	9	647·5251	·3332	37
40	271·3191		36	35		695·1417	40	704·8583		35
		·1168			·6633				·3367	
1	328·4359		38	36	·6597	697·8050	1	762·1950	·3403	36
		·1206								
2	385·5565		38	36	·6561	700·4647	2	819·5353	·3439	36
		·1244								
3	442·6809		37	36	·6525	703·1208	3	876·8792	·3475	36
		·1281								
4	499·8090		37	35	·6490	705·7733	4	934·2267	·3510	35
		·1318								
45	556·9408		37	37	·6453	708·4223	45	75991·5777	·3547	37
		·1355								
6	614·0763		37	35	·6418	711·0676	6	76048·9324	·3582	35
		·1392								
7	671·2155		38	36	·6382	713·7094	7	106·2906	·3618	36
		·1430								
8	728·3585		36	36	·6346	716·3476	8	163·6524	·3654	36
		·1466								
9	785·5051	·1504	38	36	·6310	718·9822	9	221·0178	·3690	36
50	842·6555		37	35		721·6132	50	278·3868		35
		·1541			·6275				·3725	
1	899·8096		37	36	·6239	724·2407	1	335·7593	·3761	36
		·1578								
2	72956·9674		37	36	·6203	726·8646	2	393·1354	·3797	36
		·1615								
3	73014·1289		37	36	·6167	729·4849	3	450·5151	·3833	36
		·1652								
4	071·2941		38	35	·6132	732·1016	4	507·8984	·3868	35
		·1689								
55	128·4630		36	35	·6097	734·7148	55	565·2852	·3903	35
		·1727								
6	185·6357		37	36	·6061	737·3245	6	622·6755	·3939	36
		·1763								
7	242·8120		37	36	·6025	739·9306	7	680·0694	·3975	36
		·1800								
8	299·9920		37	36	·5989	742·5331	8	737·4669	·4011	36
		·1837								
9	357·1757		37	35		745·1320	9	794·8680		35
		57·1874			2·5954				57·4046	
60	73414·3631					160747·7274	60	76852·2726		

Δ².	Diff.	66°.	,	−66°.	Diff.	Δ².	Δ².	Diff.	67°.
	"	"		"	"			"	"
35		160747·7274	0	76852·2726		35	35		160897·0403
	2·5919				57·4081			2·3831	
36	·5883	750·3193	1	909·6807	·4117	36	33	·3798	899·4231
35	·5848	752·9076	2	76967·0924	·4152	35	35	·3763	901·8032
36	·5812	755·4924	3	77024·5076	·4188	36	34	·3729	904·1795
35	·5777	758·0736	4	081·9264	·4223	35	34	·3695	906·5521
35	·5742	760·6513	5	139·3487	·4258	35	33	·3662	908·9219
36	·5706	763·2255	6	196·7745	·4294	36	35	·3627	911·2881
35	·5671	765·7961	7	254·2039	·4329	35	33	·3594	913·6508
36	·5635	768·3632	8	311·6368	·4365	36	35	·3559	916·0102
35	·5600	770·9267	9	369·0733	·4400	35	33	·3526	918·3661
35	·5565	773·4867	10	426·5133	·4435	35	34	·3492	920·7187
35	·5530	776·0432	1	483·9568	·4470	35	34	·3458	923·0679
36	·5494	778·5962	2	541·4038	·4506	36	34	·3424	925·4137
34	·5460	781·1456	3	598·8544	·4540	34	34	·3390	927·7561
36	·5424	783·6916	4	656·3084	·4576	36	33	·3357	930·0951
35	·5389	786·2340	15	713·7660	·4611	35	34	·3323	932·4308
35	·5354	788·7729	6	771·2271	·4646	35	34	·3289	934·7631
36	·5318	791·3083	7	828·6917	·4682	36	34	·3255	937·0920
34	·5284	793·8401	8	886·1599	·4716	34	33	·3222	939·4175
35	·5249	796·3685	9	77943·6315	·4751	35	34	·3188	941·7397
36	·5213	798·8934	20	78001·1066	·4787	36	33	·3155	944·0585
34	·5179	801·4147	1	058·5853	·4821	34	35	·3120	946·3740
36	·5143	803·9326	2	116·0674	·4857	36	32	·3088	948·6860
34	·5109	806·4469	3	173·5531	·4891	34	35	·3053	950·9948
35	·5074	808·9578	4	231·0422	·4926	35	33	·3020	953·3001
35	·5039	811·4652	25	288·5348	·4961	35	33	·2987	955·6021
35	·5004	813·9691	6	346·0309	·4996	35	34	·2953	957·9008
35	·4969	816·4695	7	403·5305	·5031	35	33	·2920	960·1961
35	·4934	818·9664	8	461·0336	·5066	35	34	·2886	962·4881
35	·4899	821·4598	9	518·5402	·5101	35	33	·2853	964·7767
34	·4865	823·9497	30	576·0503	·5135	34	33	·2820	967·0620
35	·4830	826·4362	1	633·5638	·5170	35	34	·2786	969·3440
35	·4795	828·9192	2	691·0808	·5205	35	34	·2752	971·6226
35	·4760	831·3987	3	748·6013	·5240	35	32	·2720	973·8978
34	·4726	833·8747	4	806·1253	·5274	34	34	·2686	976·1698
35	·4691	836·3473	35	863·6527	·5309	35	33	·2653	978·4384
35	·4656	838·8164	6	921·1836	·5344	35	34	·2619	980·7037
35	·4621	841·2820	7	78978·7180	·5379	35	33	·2586	982·9656
34	·4587	843·7441	8	79036·2559	·5413	34	32	·2554	985·2242
34	·4553	846·2028	9	093·7972	·5447	34	34	·2520	987·4796
35	·4518	848·6581	40	151·3419	·5482	35	34	·2486	989·7316
35	·4483	851·1099	1	208·8901	·5517	35	32	·2454	991·9802
34	·4449	853·5582	2	266·4418	·5551	34	33	·2421	994·2256
35	·4414	856·0031	3	323·9969	·5586	35	34	·2387	996·4677
34	·4380	858·4445	4	381·5555	·5620	34	33	·2354	160998·7064
34	·4346	860·8825	45	439·1175	·5654	34	32	·2322	161000·9418
35	·4311	863·3171	6	496·6829	·5689	35	34	·2288	003·1740
35	·4276	865·7482	7	554·2518	·5724	35	33	·2255	005·4028
34	·4242	868·1758	8	611·8242	·5758	34	32	·2223	007·6283
34	·4208	870·6000	9	669·4000	·5792	34	34	·2189	009·8506
34	·4174	873·0208	50	726·9792	·5826	34	32	·2157	012·0695
35	·4139	875·4382	1	784·5618	·5861	35	34	·2123	014·2852
34	·4105	877·8521	2	842·1479	·5895	34	32	·2091	016·4975
34	·4071	880·2626	3	899·7374	·5929	34	33	·2058	018·7066
35	·4036	882·6697	4	79957·3303	·5964	35	33	·2025	020·9124
34	·4002	885·0733	55	80014·9267	·5998	34	33	·1992	023·1149
34	·3968	887·4735	6	072·5265	·6032	34	33	·1959	025·3141
34	·3934	889·8703	7	130·1297	·6066	34	32	·1927	027·5100
34	·3900	892·2637	8	187·7363	·6100	34	33	·1894	029·7027
34		894·6537	9	245·3463		34	33		031·8921
	2·3866				57·6134			2·1861	
		160897·0403	60	80302·9597					161034·0782

′	−67°.	Diff.	Δ².	Δ².	Diff.	68°.	′	−68°.	Diff.	Δ².
	″	″			″	″		″	″	
0	80302·9597	57·6169	35	32	2·1829	161034·0782	0	83765·9218	57·8171	32
1	360·5766	·6202	33	34	·1795	036·2611	1	823·7389	·8205	34
2	418·1968	·6237	35	32	·1763	038·4406	2	881·5594	·8237	32
3	475·8205	·6271	34	32	·1731	040·6169	3	939·3831	·8269	32
4	533·4476	·6305	34	33	·1698	042·7900	4	83997·2100	·8302	33
5	591·0781	·6338	33	33	·1665	044·9598	5	84055·0402	·8335	33
6	648·7119	·6373	35	32	·1633	047·1263	6	112·8737	·8367	32
7	706·3492	·6406	33	32	·1601	049·2896	7	170·7104	·8399	32
8	763·9898	·6441	35	33	·1568	051·4497	8	228·5503	·8432	33
9	821·6339	·6474	33	33	·1535	053·6065.	9	286·3935	·8465	33
10	879·2813	·6508	34	32	·1503	055·7600	10	344·2400	·8497	32
1	936·9321	·6542	34	33	·1470	057·9103	1	402·0897	·8530	33
2	80994·5863	·6576	34	32	·1438	060·0573	2	459·9427	·8562	32
3	81052·2439	·6610	34	32	·1406	062·2011	3	517·7989	·8594	32
4	109·9049	·6643	33	33	·1373	064·3417	4	575·6583	·8627	33
15	167·5692	·6677	34	32	·1341	066·4790	15	633·5210	·8659	32
6	225·2369	·6711	34	32	·1309	068·6131	6	691·3869	·8691	32
7	282·9080	·6745	34	33	·1276	070·7440	7	749·2560	·8724	33
8	340·5825.	·6778	33	32	·1244	072·8716	8	807·1284	·8756	32
9	398·2603	·6812	34	32	·1212	074·9960	9	865·0040	·8788	32
20	455·9415	·6845	33	32	·1180	077·1172	20	922·8828	·8820	32
1	513·6260	·6880	35	33	·1147	079·2352	1	84980·7648	·8853	33
2	571·3140	·6912	32	31	·1116	081·3499	2	85038·6501	·8884	31
3	629·0052	·6947	35	33	·1083	083·4615.	3	096·5385	·8917	33
4	686·6999	·6980	33	32	·1051	085·5698	4	154·4302	·8949	32
25	744·3979	·7013	33	33	·1018	087·6749	25	212·3251	·8982	33
6	802·0992	·7047	34	31	·0987	089·7767	6	270·2233	·9013	31
7	859·8039	·7080	33	32	·0955	091·8754	7	328·1246	·9045	32
8	917·5119	·7114	34	32	·0923	093·9709	8	386·0291	·9077	32
9	81975·2233	·7147	33	33	·0890	096·0632	9	443·9368	·9110	33
30	82032·9380	·7180	33	31	·0859	098·1522	30	501·8478	·9141	31
1	090·6560	·7214	34	32	·0827	100·2381	1	559·7619	·9173	32
2	148·3774	·7248	34	32	·0795	102·3208	2	617·6792	·9205	32
3	206·1022	·7280	32	32	·0763	104·4003	3	675·5997	·9237	32
4	263·8302	·7314	34	32	·0731	106·4766	4	733·5234	·9269	32
35	321·5616	·7347	33	32	·0699	108·5497	35	791·4503	·9301	32
6	379·2963	·7381	34	32	·0667	110·6196	6	849·3804	·9333	32
7	437·0344	·7414	33	31	·0636	112·6863	7	907·3137	·9364	31
8	494·7758	·7446	32	32	·0604	114·7499	8	85965·2501	·9396	32
9	552·5204	·7480	34	32	·0572	116·8103	9	86023·1897	·9428	32
40	610·2684	·7514	34	32	·0540	118·8675.	40	081·1325	·9460	32
1	668·0198	·7546	32	32	·0508	120·9215.	1	139·0785	·9492	32
2	725·7744	·7579	33	31	·0477	122·9723	2	197·0277	·9523	31
3	783·5323	·7613	34	32	·0445	125·0200	3	254·9800	·9555	32
4	841·2936	·7646	33	31	·0414	127·0645	4	312·9355.	·9586	31
45	899·0582	·7678	32	32	·0382	129·1059	45	370·8941	·9618	32
6	82956·8260	·7712	34	32	·0350	131·1441	6	428·8559	·9650	32
7	83014·5972	·7745	33	32	·0318	133·1791	7	486·8209	·9682	32
8	072·3717	·7777	32	31	·0287	135·2109	8	544·7891	·9713	31
9	130·1494	·7811	34	31	·0256	137·2396	9	602·7604	·9744	31
50	187·9305.	·7843	32	32	·0224	139·2652	50	660·7348	·9776	32
1	245·7148	·7877	34	31	·0193	141·2876	1	718·7124	·9807	31
2	303·5025.	·7909	32	32	·0161	143·3069	2	776·6931	·9839	32
3	361·2934	·7942	33	32	·0129	145·3230	3	834·6770	·9871	32
4	419·0876	·7975	33	30	·0099	147·3359	4	892·6641	·9901	30
55	476·8851	·8008	33	32	·0067	149·3458	55	86950·6542	·9933	32
6	534·6859	·8041	33	32	·0035	151·3525.	6	87008·6475	·9965	32
7	592·4900	·8073	32	31	2·0004	153·3560	7	066·6440	57·9996	31
8	650·2973	·8106	33	31	1·9973	155·3564	8	124·6436	58·0027	31
9	708·1079	57·8139	33	32	1·9941	157·3537	9	182·6463	58·0059	32
50	83765·9218					161159·3478	60	87240·6522		

Δ².	Diff.	69°.	′	−69°.	Diff.	Δ².	Δ².	Diff.	70°.
	″	″		″	″			″	″
30	1·9911	161159·3478	0	87240·6522	58·0089	30	30	1·8077	161273·3593
32	·9879	161·3389	1	298·6611	·0121	32	29	·8048	275·1670
32	·9847	163·3268	2	356·6732	·0153	32	31	·8017	276·9718
30	·9817	165·3115	3	414·6885.	·0183	30	29	·7988	278·7735
32	·9785	167·2932	4	472·7068	·0215	32	30	·7958	280·5723
31	·9754	169·2717	5	530·7283	·0246	31	29	·7929	282·3681
30	·9724	171·2471	6	588·7529	·0276	30	30	·7899	284·1610
32	·9692	173·2195.	7	646·7805	·0308	32	30	·7869	285·9509
31	·9661	175·1887	8	704·8113	·0339	31	30	·7839	287·7378
32	·9629	177·1548	9	762·8452	·0371	32	29	·7810	289·5217
30	·9599	179·1177	10	820·8823	·0401	30	30	·7780	291·3027
31	·9568	181·0776	1	878·9224	·0432	31	30	·7750	293·0807
31	·9537	183·0344	2	936·9656	·0463	31	29	·7721	294·8557
31	·9506	184·9881	3	87995·0119	·0494	31	29	·7692	296·6278
31	·9475	186·9387	4	88053·0613	·0525	31	30	·7662	298·3970
31	·9444	188·8862	15	111·1138	·0556	31	30	·7632	300·1632
31	·9413	190·8306	6	169·1694	·0587	31	29	·7603	301·9264
31	·9382	192·7719	7	227·2281	·0618	31	29	·7574	303·6867
31	·9351	194·7101	8	285·2899	·0649	31	30	·7544	305·4441
31	·9320	196·6452	9	343·3548	·0680	31	29	·7515	307·1985
30	·9290	198·5772	20	401·4228	·0710	30	30	·7485	308·9500
31	·9259	200·5062	1	459·4938	·0741	31	29	·7456	310·6985
30	·9229	202·4321	2	517·5679	·0771	30	29	·7427	312·4441
32	·9197	204·3550.	3	575·6450	·0803	32	30	·7397	314·1868
30	·9167	206·2747	4	633·7253	·0833	30	29	·7368	315·9265
31	·9136	208·1914	25	691·8086	·0864	31	29	·7339	317·6633
30	·9106	210·1050	6	749·8950.	·0894	30	29	·7310	319·3972
32	·9074	212·0156	7	807·9844	·0926	32	30	·7280	321·1282
29	·9045	213·9230	8	866·0770	·0955	29	29	·7251	322·8562
32	·9013	215·8275.	9	924·1725	·0987	32	28	·7223	324·5813
30	·8983	217·7288	30	88982·2712	·1017	30	30	·7193	326·3036
30	·8953	219·6271	1	89040·3729	·1047	30	29	·7164	328·0229
31	·8922	221·5224	2	098·4776	·1078	31	30	·7134	329·7393
31	·8891	223·4146	3	156·5854	·1109	31	28	·7106	331·4527
30	·8861	225·3037	4	214·6963	·1139	30	29	·7077	333·1633
30	·8831	227·1898	35	272·8102	·1169	30	29	·7048	334·8710
31	·8800	229·0729	6	330·9271	·1200	31	30	·7018	336·5758
30	·8770	230·9529	7	389·0471	·1230	30	28	·6990	338·2776
30	·8740	232·8299	8	447·1701	·1260	30	29	·6961	339·9766
31	·8709	234·7039	9	505·2961	·1291	31	29	·6932	341·6727
31	·8678	236·5748	40	563·4252	·1322	31	29	·6903	343·3659
29	·8649	238·4426	1	621·5574	·1351	29	29	·6874	345·0562
31	·8618	240·3075.	2	679·6925	·1382	31	29	·6845	346·7436
30	·8588	242·1693	3	737·8307	·1412	30	28	·6817	348·4281
30	·8558	244·0281	4	795·9719	·1442	30	30	·6787	350·1098
31	·8527	245·8839	45	854·1161	·1473	31	28	·6759	351·7885
30	·8497	247·7366	6	912·2634	·1503	30	29	·6730	353·4644
29	·8468	249·5863	7	89970·4137	·1532	29	28	·6702	355·1374
31	·8437	251·4331	8	90028·5669	·1563	31	29	·6673	356·8076
31	·8406	253·2768	9	086·7232	·1594	31	29	·6644	358·4749
29	·8377	255·1174	50	144·8826	·1623	29	29	·6615	360·1393
30	·8347	256·9551	1	203·0449	·1653	30	28	·6587	361·8008
30	·8317	258·7898	2	261·2102	·1683	30	29	·6558	363·4595
30	·8287	260·6215.	3	319·3785	·1713	30	28	·6530	365·1153
31	·8256	262·4502	4	377·5498	·1744	31	29	·6501	366·7683
29	·8227	264·2758	55	435·7242	·1773	29	29	·6472	368·4185
30	·8197	266·0985	6	493·9015.	·1803	30	28	·6444	370·0658
30	·8167	267·9182	7	552·0818	·1833	30	28	·6416	371·7102
30	·8137	269·7349	8	610·2651	·1863	30	29	·6387	373·3517
30	·8107	271·5486	9	668·4514	58·1893	30	28	·6359	374·9904
	1·8107	161273·3593	60	90726·6407				1·6359	161376·6263

′	−70°.	Diff.	Δ².	Δ².	Diff.	71°.	′	−71°.	Diff.	Δ².
	″	″			″	″		″	″	
0	90726·6407		30	29	1·6330	161376·6262	0	94223·3738		29
		58·1923							58·3670	
1	784·8330	·1952	29	29	·6301	378·2592	1	281·7408	·3699	29
2	843·0282	·1983	31	27	·6274	379·8893	2	340·1107	·3726	27
3	901·2265	·2012	29	29	·6245	381·5167	3	398·4833	·3755	29
4	90959·4277	·2042	30	28	·6217	383·1412	4	456·8588	·3783	28
5	91017·6319	·2071	29	29	·6188	384·7629	5	515·2371	·3812	29
6	075·8390	·2101	30	27	·6161	386·3817	6	573·6183	·3839	27
7	134·0491	·2131	30	29	·6132	387·9978	7	632·0022	·3868	29
8	192·2622	·2161	30	28	·6104	389·6110	8	690·3890	·3896	28
9	250·4783	·2190	29	29	·6075	391·2214	9	748·7786	·3925	29
10	308·6973	·2220	30	27	·6048	392·8289	10	807·1711	·3952	27
1	366·9193	·2250	30	29	·6019	394·4337	1	865·5663	·3981	29
2	425·1443	·2279	29	28	·5991	396·0356	2	923·9644	·4009	28
3	483·3722	·2308	29	28	·5963	397·6347	3	94982·3653	·4037	28
4	541·6030	·2338	30	28	·5935	399·2310	4	95040·7690	·4065	28
15	599·8368	·2368	30	28	·5907	400·8245	15	099·1755	·4093	28
6	658·0736	·2397	29	28	·5879	402·4152	6	157·5848	·4121	28
7	716·3133	·2426	29	28	·5851	404·0031	7	215·9969	·4149	28
8	774·5559	·2456	30	28	·5823	405·5882	8	274·4118	·4177	28
9	832·8015	·2485	29	28	·5795	407·1705	9	332·8295	·4205	28
20	891·0500	·2515	30	28	·5767	408·7500	20	391·2500	·4233	28
1	91949·3015	·2544	29	28	·5739	410·3267	1	449·6733	·4261	28
2	92007·5559	·2573	29	28	·5711	411·9006	2	508·0994	·4289	28
3	065·8132	·2603	30	27	·5684	413·4717	3	566·5283	·4316	27
4	124·0735	·2632	29	29	·5655	415·0401	4	624·9599	·4345	29
25	182·3367	·2661	29	27	·5628	416·6056	25	683·3944	·4372	27
6	240·6028	·2690	29	28	·5600	418·1684	6	741·8316	·4400	28
7	298·8718	·2720	30	28	·5572	419·7284	7	800·2716	·4428	28
8	357·1438	·2749	29	27	·5545	421·2856	8	858·7144	·4455	27
9	415·4187	·2777	28	29	·5516	422·8401	9	917·1599	·4484	29
30	473·6964	·2807	30	27	·5489	424·3917	30	95975·6083	·4511	27
1	531·9771	·2836	29	27	·5462	425·9406	1	96034·0594	·4538	27
2	590·2607	·2866	30	28	·5434	427·4868	2	092·5132	·4566	28
3	648·5473	·2894	28	28	·5406	429·0302	3	150·9698	·4594	28
4	706·8367	·2923	29	27	·5378	430·5708	4	209·4292	·4622	28
35	765·1290	·2952	29	27	·5351	432·1086	35	267·8914	·4649	27
6	823·4242	·2982	30	27	·5324	433·6437	6	326·3563	·4676	27
7	881·7224	·3010	28	28	·5296	435·1761	7	384·8239	·4704	28
8	940·0234	·3039	29	28	·5268	436·7057	8	443·2943	·4732	28
9	92998·3273	·3068	29	27	·5241	438·2325	9	501·7675	·4759	27
40	93056·6341	·3097	29	27	·5214	439·7566	40	560·2434	·4786	27
1	114·9438	·3126	29	28	·5186	441·2780	1	618·7220	·4814	28
2	173·2564	·3155	29	28	·5158	442·7966	2	677·2034	·4842	28
3	231·5719	·3183	28	27	·5131	444·3124	3	735·6876	·4869	27
4	289·8902	·3213	30	27	·5104	445·8255	4	794·1745	·4896	27
45	348·2115	·3241	28	27	·5077	447·3359	45	852·6641	·4923	27
6	406·5356	·3270	29	28	·5049	448·8436	6	911·1564	·4951	28
7	464·8626	·3298	28	27	·5022	450·3485	7	96969·6515	·4978	27
8	523·1924	·3327	29	27	·4995	451·8507	8	97028·1493	·5005	27
9	581·5251	·3356	29	27	·4968	453·3502	9	086·6498	·5032	27
50	639·8607	·3385	29	28	·4940	454·8470	50	145·1530	·5060	28
1	698·1992	·3413	28	27	·4913	456·3410	1	203·6590	·5087	27
2	756·5405	·3442	29	27	·4886	457·8323	2	262·1677	·5114	27
3	814·8847	·3470	28	27	·4859	459·3209	3	320·6791	·5141	27
4	873·2317	·3499	29	28	·4832	460·8068	4	379·1932	·5168	27
5	931·5816	·3528	29	26	·4804	462·2900	55	437·7100	·5196	28
6	93989·9344	·3556	28	28	·4778	463·7704	6	496·2296	·5222	26
7	94048·2900	·3584	28	26	·4750	465·2482	7	554·7518	·5250	28
8	106·6484	·3613	29	28	·4724	466·7232	8	613·2768	·5276	26
9	165·0097		28			468·1956	9	671·8044		28
60	94223·3738	58·3641			1·4696	161469·6652	60	97730·3348	58·5304	

Δ°.	Diff.	72°.	′	−72°.	Diff.	Δ°.	Δ°.	Diff.	73°.
	″	″		″	″			″	″
26		161469·6652	0	97730·3348		26			161552·9965
27	1·4670	471·1322	1	788·8678	58·5330	27	25	1·3096	554·3061
28	·4643	472·5965	2	847·4035	·5357	28	26	·3070	555·6131
26	·4615	474·0580	3	905·9420	·5385	26	25	·3045	556·9176
27	·4589	475·5169	4	97964·4831	·5411	26	25	·3020	558·2196
27	·4562	476·9731	5	98023·0269	·5438	27	26	·2994	559·5190
27	·4535	478·4266	6	081·5734	·5465	27	26	·2968	560·8158
26	·4508	479·8774	7	140·1226	·5492	27	25	·2943	562·1101
27	·4482	481·3256	8	198·6744	·5518	26	25	·2918	563·4019
27	·4455	482·7711	9	257·2289	·5545	27	25	·2893	564·6912
					·5572		26	·2867	
27	·4401	484·2139	10	315·7861	·5599	27	25	·2842	565·9778
27	·4374	485·6540	1	374·3460	·5626	27	25	·2817	567·2618
26	·4348	487·0914	2	432·9086	·5652	26	25	·2792	568·5431
27	·4321	488·5262	3	491·4738	·5679	27	26	·2766	569·8218
26	·4295	489·9583	4	550·0417	·5705	26	25	·2741	571·0978
27	·4268	491·3878	15	608·6122	·5732	27	25	·2716	572·3712
27	·4241	492·8146	6	667·1854	·5759	27	25	·2691	573·6419
26	·4215	494·2387	7	725·7613	·5785	26	25	·2666	574·9110
27	·4188	495·6602	8	784·3398	·5812	27	26	·2640	576·1774
26	·4162	497·0790	9	842·9210	·5838	26	24	·2616	577·4412
27	·4135	498·4952	20	901·5048	·5865	27	25	·2591	578·7026
26	·4109	499·9087	1	98960·0913	·5891	26	26	·2565	579·9615
26	·4083	501·3196	2	99018·6804	·5917	26	24	·2541	581·2228
27	·4056	502·7279	3	077·2721	·5944	27	25	·2516	582·4767
27	·4029	504·1335	4	135·8665	·5971	27	25	·2491	583·7279
26	·4003	505·5364	25	194·4636	·5997	26	26	·2465	584·9766
26	·3977	506·9367	6	253·0633	·6023	26	24	·2441	586·2231
26	·3951	508·3344	7	311·6656	·6049	26	24	·2417	587·4672
27	·3924	509·7295	8	370·2705	·6076	27	26	·2391	588·7089
26	·3898	511·1219	9	428·8781	·6102	26	25	·2366	589·9481
26	·3872	512·5117	30	487·4883	·6128	26	24	·2342	591·1847
26	·3846	513·8989	1	546·1011	·6154	26	25	·2317	592·4190
27	·3819	515·2835	2	604·7165	·6181	27	25	·2292	593·6508
26	·3793	516·6654	3	663·3346	·6207	26	24	·2268	594·8801
26	·3767	518·0447	4	721·9553	·6233	26	26	·2242	596·1069
26	·3741	519·4214	35	780·5786	·6259	26	24	·2218	597·3312
26	·3715	520·7955	6	839·2045	·6285	26	24	·2194	598·5530
26	·3689	522·1670	7	897·8330	·6311	26	25	·2169	599·7723
26	·3663	523·5359	8	99956·4641	·6337	26	25	·2144	600·9891
27	·3636	524·9022	9	100015·0978	·6364	27	24	·2120	602·2035
25	·3611	526·2658	40	073·7342	·6389	25	25	·2095	603·4153
26	·3585	527·6269	1	132·3731	·6415	26	24	·2071	604·6247
26	·3559	528·9854	2	191·0146	·6441	26	25	·2046	605·8316
26	·3533	530·3413	3	249·6587	·6467	26	24	·2022	607·0360
26	·3507	531·6946	4	308·3054	·6493	26	25	·1997	608·2379
26	·3481	533·0453	45	366·9547	·6519	26	24	·1973	609·4373
26	·3455	534·3934	6	425·6066	·6545	26	25	·1948	610·6342
26	·3429	535·7389	7	484·2611	·6571	26	24	·1924	611·8286
25	·3404	537·0818	8	542·9182	·6596	25	24	·1900	613·0205
26	·3378	538·4222	9	601·5778	·6622	26	25	·1875	614·2099
26	·3352	539·7600	50	660·2400	·6648	26	24	·1851	615·4968
26	·3326	541·0952	1	718·9048	·6674	26	24	·1827	616·7812
25	·3301	542·4278	2	777·5722	·6699	25	24	·1803	617·7631
26	·3275	543·7579	3	836·2421	·6725	26	25	·1778	618·9426
26	·3249	545·0854	4	894·9146	·6751	26	24	·1754	620·1196
26	·3223	546·4103	55	100953·5897	·6777	26	24	·1730	621·2942
24	·3199	547·7326	6	101012·2674	·6801	24	24	·1706	622·4663
27	·3172	549·0525	7	070·9475	·6828	27	24	·1682	623·6359
25	·3147	550·3697	8	129·6303	·6853	25	25	·1657	624·8031
26	·3121	551·6844	9	188·3156	·6879	26	23	·1634	625·9678
	1·3121	161552·9965	60	101247·0035				1·1634	161627·1412

′	−73°.	Diff.	Δ¹.	Δ².	Diff.	74°.	′	−74°.	Diff.	Δ¹.
	″	″			″	″		″	″	
0	101247·0035.	58·6904	25	25	1·1609	161627·1429	0	104772·8571	58·8391	25
1	305·6939	·6930	26	23	·1586	628·3038	1	831·6962	·8414	23
2	364·3869	·6955	25	25	·1561	629·4624	2	890·5376	·8439	25
3	423·0824	·6980	25	23	·1538	630·6185	3	104949·3815.	·8462	23
4	481·7804	·7006	26	25	·1513	631·7723	4	105008·2277	·8487	25
5	540·4810	·7032	26	23	·1490	632·9236	5	067·0764	·8510	23
6	599·1842	·7057	25	25	·1465	634·0726	6	125·9274	·8535	25
7	657·8899	·7082	25	23	·1442	635·2191	7	184·7809	·8558	23
8	716·5981	·7107	25	24	·1418	636·3633	8	243·6367	·8582	24
9	775·3088	·7133	26	24	·1394	637·5051	9	302·4949	·8606	24
10	834·0221	·7158	25	23	·1371	638·6445.	10	361·3555	·8629	23
1	892·7379	·7183	25	25	·1346	639·7816	1	420·2184	·8654	25
2	101951·4562	·7208	25	23	·1323	640·9162	2	479·0838	·8677	23
3	102010·1770	·7234	26	24	·1299	642·0485.	3	537·9515	·8701	24
4	068·9004	·7259	25	24	·1275	643·1784	4	596·8216	·8725	24
15	127·6263	·7284	25	23	·1252	644·3059	15	655·6941	·8748	23
6	186·3547	·7309	25	24	·1228	645·4311	6	714·5689	·8772	24
7	245·0856	·7334	25	24	·1204	646·5539	7	773·4461	·8796	24
8	303·8190	·7360	26	23	·1181	647·6743	8	832·3257	·8819	23
9	362·5550.	·7384	24	24	·1157	648·7924	9	891·2076	·8843	24
20	421·2934	·7409	25	24	·1133	649·9081	20	105950·0919	·8867	24
1	480·0343	·7435	26	23	·1110	651·0214	1	106008·9786	·8890	23
2	538·7778	·7459	24	23	·1087	652·1324	2	067·8676	·8913	23
3	597·5237	·7484	25	25	·1062	653·2411	3	126·7589	·8938	25
4	656·2721	·7509	25	22	·1040	654·3473	4	185·6527	·8960	22
25	715·0230	·7535	26	24	·1016	655·4513	25	244·5487	·8984	24
6	773·7765.	·7559	24	23	·0993	656·5529	6	303·4471	·9007	23
7	832·5324	·7583	24	24	·0969	657·6522	7	362·3478	·9031	24
8	891·2907	·7609	26	23	·0946	658·7491	8	421·2509	·9054	23
9	102950·0516	·7634	25	24	·0922	659·8437	9	480·1563	·9078	24
30	103008·8150.	·7658	24	23	·0899	660·9359	30	539·0641	·9101	23
1	067·5808	·7683	25	23	·0876	662·0258	1	597·9742	·9124	23
2	126·3491	·7708	25	23	·0853	663·1134	2	656·8866	·9147	23
3	185·1199	·7732	24	23	·0830	664·1987	3	715·8013	·9170	23
4	243·8931	·7758	26	24	·0806	665·2817	4	774·7183	·9194	24
35	302·6689	·7782	24	23	·0783	666·3623	35	833·6377	·9217	23
6	361·4471	·7806	24	24	·0759	667·4406	6	892·5594	·9241	24
7	420·2277	·7831	25	22	·0737	668·5165	7	106951·4835.	·9263	22
8	479·0108	·7856	25	23	·0714	669·5902	8	107010·4098	·9286	23
9	537·7964	·7880	24	24	·0690	670·6616	9	069·3384	·9310	24
40	596·5844	·7905	25	23	·0667	671·7306	40	128·2694	·9333	23
1	655·3749	·7929	24	22	·0645	672·7973	1	187·2027	·9355	22
2	714·1678	·7954	25	24	·0621	673·8618	2	246·1382	·9379	24
3	772·9632	·7978	24	23	·0598	674·9239	3	305·0761	·9402	23
4	831·7610	·8003	25	23	·0575	675·9837	4	364·0163	·9425	23
5	890·5613	·8027	24	22	·0553	677·0412	45	422·9588	·9447	22
6	103949·3640	·8052	25	24	·0529	678·0965.	6	481·9035	·9471	24
7	104008·1692	·8076	24	22	·0507	679·1494	7	540·8506	·9493	22
8	066·9768	·8100	24	24	·0483	680·2001	8	599·7999	·9517	24
9	125·7868	·8125	25	22	·0461	681·2484	9	658·7516	·9539	22
50	184·5993	·8149	24	23	·0438	682·2945	50	717·7055.	·9562	23
1	243·4142	·8173	24	23	·0415	683·3383	1	776·6617	·9585	23
2	302·2315.	·8197	24	23	·0392	684·3798	2	835·6202	·9608	23
3	361·0512	·8222	25	22	·0370	685·4190	3	894·5810	·9630	22
4	419·8734	·8246	24	23	·0347	686·4560	4	107953·5440	·9653	23
5	478·6980	·8270	24	23	·0324	687·4907	55	108012·5093	·9676	23
6	537·5250.	·8294	24	23	·0301	688·5231	6	071·4769	·9699	23
7	596·3544	·8318	24	22	·0279	689·5532	7	130·4468	·9721	22
8	655·1862	·8343	25	23	·0256	690·5811	8	189·4189	·9744	23
9	714·0205.	58·8366	23	22	1·0234	691·6067	9	248·3933	58·9766	22
	104772·8571					161692·6301	60	108307·3699		

Δ².	Diff.	75°.	′	−75°.	Diff.	Δ².	Δ².	Diff.	76°.
	″	″		″	″			″	″
23	1·0211	161692·6301	0	108307·3699	58·9789	23	22	0·8900	161749·9865
23	·0188	693·6512	1	366·3488	·9812	23	20	·8880	750·8765
22	·0166	694·6700	2	425·3300	·9834	22	21	·8859	751·7645
23	·0143	695·6866	3	484·3134	·9857	23	22	·8837	752·6504
22	·0121	696·7009	4	543·2991	·9879	22	20	·8817	753·5341
22	·0099	697·7130	5	602·2870	·9901	22	22	·8795	754·4158
23	·0076	698·7229	6	661·2771	·9924	23	20	·8775	755·2953
23	·0053	699·7305	7	720·2695	·9947	23	22	·8753	756·1728
22	·0031	700·7358	8	779·2642	·9969	22	20	·8733	757·0481
22	1·0009	701·7389	9	838·2611	58·9991	22	21	·8712	757·9214
22	0·9987	702·7398	10	897·2602	59·0013	22	21	·8691	758·7926
23	·9964	703·7385	1	108956·2615	·0036	23	21	·8670	759·6617
22	·9942	704·7349	2	109015·2651	·0058	22	21	·8649	760·5287
23	·9919	705·7291	3	074·2709	·0081	23	20	·8629	761·3936
21	·9898	706·7210	4	133·2790	·0102	21	21	·8608	762·2565
23	·9875	707·7108	15	192·2892	·0125	23	21	·8587	763·1173
22	·9853	708·6983	6	251·3017	·0147	22	21	·8566	763·9760
23	·9830	709·6836	7	310·3164	·0170	23	20	·8546	764·8326
21	·9809	710·6666	8	369·3334	·0191	21	21	·8525	765·6872
23	·9786	711·6475	9	428·3525	·0214	23	21	·8504	766·5397
21	·9765	712·6261	20	487·3739	·0235	21	21	·8483	767·3901
23	·9742	713·6026	1	546·3974	·0258	23	20	·8463	768·2384
22	·9720	714·5768	2	605·4232	·0280	22	20	·8443	769·0847
21	·9699	715·5488	3	664·4512	·0301	21	21	·8422	769·9290
23	·9676	716·5187	4	723·4813	·0324	23	21	·8401	770·7712
22	·9654	717·4863	25	782·5137	·0346	22	20	·8381	771·6113
21	·9633	718·4517	6	841·5483	·0367	21	20	·8361	772·4494
23	·9610	719·4150	7	900·5850	·0390	23	21	·8340	773·2855
22	·9588	720·3760	8	109959·6240	·0412	22	20	·8320	774·1195
21	·9567	721·3348	9	110018·6652	·0433	21	21	·8299	774·9515
22	·9545	722·2915	30	077·7085	·0455	22	20	·8279	775·7814
22	·9523	723·2460	1	136·7540	·0477	22	21	·8258	776·6093
22	·9501	724·1983	2	195·8017	·0499	22	20	·8238	777·4351
22	·9479	725·1484	3	254·8516	·0521	22	20	·8218	778·2589
21	·9458	726·0963	4	313·9037	·0542	21	20	·8198	779·0807
22	·9436	727·0421	35	372·9579	·0564	22	21	·8177	779·9005
22	·9414	727·9857	6	432·0143	·0586	22	20	·8157	780·7182
21	·9393	728·9271	7	491·0729	·0607	21	20	·8137	781·5339
22	·9371	729·8664	8	550·1336	·0629	22	20	·8117	782·3476
22	·9349	730·8035	9	609·1965	·0651	22	21	·8096	783·1593
22	·9327	731·7384	40	668·2616	·0673	22	19	·8077	783·9689
21	·9306	732·6711	1	727·3289	·0694	21	21	·8056	784·7766
21	·9285	733·6017	2	786·3983	·0715	21	19	·8037	785·5822
22	·9263	734·5302	3	845·4698	·0737	22	21	·8016	786·3859
22	·9241	735·4565	4	904·5435	·0759	22	20	·7996	787·1875
21	·9220	736·3806	45	110963·6194	·0780	21	20	·7976	787·9871
21	·9199	737·3026	6	111022·6974	·0801	21	19	·7957	788·7847
22	·9177	738·2225	7	081·7775	·0823	22	21	·7936	789·5804
21	·9156	739·1402	8	140·8598	·0844	21	20	·7916	790·3740
22	·9134	740·0558	9	199·9442	·0866	22	19	·7897	791·1656
21	·9113	740·9692	50	259·0308	·0887	21	21	·7876	791·9553
21	·9092	741·8805	1	318·1195	·0908	21	19	·7857	792·7429
22	·9070	742·7897	2	377·2103	·0930	22	20	·7837	793·5286
21	·9049	743·6967	3	436·3033	·0951	21	20	·7817	794·3123
21	·9028	744·6016	4	495·3984	·0972	21	20	·7797	795·0940
22	·9006	745·5044	55	554·4956	·0994	22	19	·7778	795·8737
20	·8986	746·4050	6	613·5950	·1014	20	20	·7758	796·6515
22	·8964	747·3036	7	672·6964	·1036	22	20	·7738	797·4273
21	·8943	748·2000	8	731·8000	·1057	21	20	·7718	798·2011
21	0·8922	749·0943	9	790·9057	59·1078	21	19	0·7699	798·9729
		161749·9865	60	111850·0135					161799·7428

−76°.	Diff.	Δ².	Δ².	Diff.	77°.	′	−77°.	Diff.	Δ².
″	″			″	″		″	″	
111850·0135		22	20	0·7679	161799·7428	0	115400·2572		20
	59·1100							59·2321	
909·1235		20	19	·7660	800·5107	1	459·4893		19
	·1120							·2340	
111968·2355		21	20	·7640	801·2767	2	518·7233		20
	·1141							·2360	
112027·3496		22	20	·7620	802·0407	3	577·9593		20
	·1163							·2380	
086·4659		20	19	·7601	802·8027	4	637·1973		19
	·1183							·2399	
145·5842		22	19	·7582	803·5628	5	696·4372		19
	·1205							·2418	
204·7047		20	20	·7562	804·3210	6	755·6790		20
	·1225							·2438	
263·8272		22	20	·7542	805·0772	7	814·9228		20
	·1247							·2458	
322·9519		20	19	·7523	805·8314	8	874·1686		19
	·1267							·2477	
382·0786		21	19	·7504	806·5837	9	933·4163		19
	·1288							·2496	
441·2074		21	20		807·3341	10	115992·6659		20
	·1309			·7484				·2516	
500·3383		21	19	·7465	808·0825	1	116051·9175		19
	·1330							·2535	
559·4713		21	20	·7445	808·8290	2	111·1710		20
	·1351							·2555	
618·6064		20	19	·7426	809·5735	3	170·4265		19
	·1371							·2574	
677·7435		21	19	·7407	810·3161	4	229·6839		19
	·1392							·2593	
736·8827		21	19	·7388	811·0568	15	288·9432		19
	·1413							·2612	
796·0240		21	19	·7369	811·7956	6	348·2044		19
	·1434							·2631	
855·1674		20	20	·7349	812·5325	7	407·4675		20
	·1454							·2651	
914·3128		21	19	·7330	813·2674	8	466·7326		19
	·1475							·2670	
112973·4603		21	19	·7311	814·0004	9	525·9996		19
	·1496							·2689	
113032·6099		21	19		814·7315	20	585·2685		19
	·1517			·7292				·2708	
091·7616		20	20	·7272	815·4607	1	644·5393		20
	·1537							·2728	
150·9153		20	18	·7254	816·1879	2	703·8121		18
	·1557							·2746	
210·0710		21	20	·7234	816·9133	3	763·0867		20
	·1578							·2766	
269·2288		21	19	·7215	817·6367	4	822·3633		19
	·1599							·2785	
328·3887		20	18	·7197	818·3582	25	881·6418		18
	·1619							·2803	
387·5506		20	20	·7177	819·0779	6	116940·9221		20
	·1639							·2823	
446·7145		21	18	·7159	819·7956	7	117000·2044		18
	·1660							·2841	
505·8805		20	20	·7139	820·5115	8	059·4885		20
	·1680							·2861	
565·0485		21	18	·7121	821·2254	9	118·7746		18
	·1701							·2879	
624·2186		20	19		821·9375	30	178·0625		19
	·1721			·7102				·2898	
683·3907		21	19	·7083	822·6477	1	237·3523		19
	·1742							·2917	
742·5649		20	19	·7064	823·3560	2	296·6440		19
	·1762							·2936	
801·7411		20	19	·7045	824·0624	3	355·9376		19
	·1782							·2955	
860·9193		20	18	·7027	824·7669	4	415·2331		18
	·1802							·2973	
920·0995		21	20	·7007	825·4696	35	474·5304		20
	·1823							·2993	
113979·2818		20	18	·6989	826·1703	6	533·8297		18
	·1843							·3011	
114038·4661		20	19	·6970	826·8692	7	593·1308		19
	·1863							·3030	
097·6524		20	18	·6952	827·5662	8	652·4338		18
	·1883							·3048	
156·8407		21	19	·6933	828·2614	9	711·7386		19
	·1904							·3067	
216·0311		19	19		828·9547	40	771·0453		19
	·1923			·6914				·3086	
275·2234		21	18	·6896	829·6461	1	830·3539		18
	·1944							·3104	
334·4178		19	19	·6877	830·3357	2	889·6643		19
	·1963							·3123	
393·6141		21	19	·6858	831·0234	3	117948·9766		19
	·1984							·3142	
452·8125		20	18	·6840	831·7092	4	118008·2908		18
	·2004							·3160	
512·0129		20	18	·6822	832·3932	45	067·6068		18
	·2024							·3178	
571·2153		19	19	·6803	833·0754	6	126·9246		19
	·2043							·3197	
630·4196		21	19	·6784	833·7557	7	186·2443		19
	·2064							·3216	
689·6260		20	18	·6766	834·4341	8	245·5659		18
	·2084							·3234	
748·8344		19	18	·6748	835·1107	9	304·8893		18
	·2103							·3252	
808·0447		21	19		835·7855	50	364·2145		19
	·2124			·6729				·3271	
867·2571		19	18	·6711	836·4584	1	423·5416		18
	·2143							·3289	
926·4714		20	19	·6692	837·1295	2	482·8705		19
	·2163							·3308	
114985·6877		20	18	·6674	837·7987	3	542·2013		18
	·2183							·3326	
115044·9060		20	18	·6656	838·4661	4	601·5339		18
	·2203							·3344	
104·1263		19	18	·6638	839·1317	55	660·8683		18
	·2222							·3362	
163·3485		20	19	·6619	839·7955	6	720·2045		19
	·2242							·3381	
222·5727		20	18	·6601	840·4574	7	779·5426		18
	·2262							·3399	
281·7989		20	18	·6583	841·1175	8	838·8825		18
	·2282							·3417	
341·0271		19	18	·6565	841·7758	9	898·2242		18
115400·2572	59·2301				161842·4323	60	118957·5677	59·3435	

Δ².	Diff.	78°.	,	−78°.	Diff.	Δ².	Δ².	Diff.	79°.
	"	"		"	"			"	"
18		161842·4323	0	118957·5677		18	16		161878·5902
19	0·6547	843·0870	1	119016·9130	59·3453	19	17	0·5504	879·1406
17	·6528	843·7398	2	076·2602	·3472	17	17	·5487	879·6893
19	·6511	844·3909	3	135·6091	·3489	19	16	·5470	880·2363
18	·6492	845·0401	4	194·9599	·3508	18	17	·5454	880·7817
17	·6474	845·6875	5	254·3125	·3526	17	16	·5437	881·3254
19	·6457	846·3332	6	313·6668	·3543	19	17	·5421	881·8675
18	·6438	846·9770	7	373·0230	·3562	18	17	·5404	882·4079
17	·6420	847·6190	8	432·3810	·3580	17	16	·5387	882·9466
19	·6403	848·2593	9	491·7407	·3597	19	16	·5371	883·4837
	·6384				·3616			·5355	
17		848·8977	10	551·1023		17	16		884·0192
18	·6367	849·5344	1	610·4656	·3633	18	17	·5339	884·5531
19	·6349	850·1693	2	669·8307	·3651	19	17	·5322	885·0853
17	·6330	850·8023	3	729·1977	·3670	17	15	·5305	885·6158
17	·6313	851·4336	4	788·5664	·3687	17	17	·5290	886·1448
19	·6296	852·0632	15	847·9368	·3704	19	17	·5273	886·6721
17	·6277	852·6909	6	907·3091	·3723	17	15	·5256	887·1977
18	·6260	853·3169	7	119966·6831	·3740	18	17	·5241	887·7218
18	·6242	853·9411	8	120026·0589	·3758	18	16	·5224	888·2442
17	·6224	854·5635	9	085·4365	·3776	17	16	·5208	888·7650
	·6207				·3793			·5192	
18		855·1842	20	144·8158		18	16		889·2842
18	·6189	855·8031	1	204·1969	·3811	18	16	·5176	889·8018
17	·6171	856·4202	2	263·5798	·3829	17	17	·5160	890·3178
18	·6154	857·0356	3	322·9644	·3846	18	16	·5143	890·8321
17	·6136	857·6492	4	382·3508	·3864	17	15	·5127	891·3448
18	·6119	858·2611	25	441·7389	·3881	18	17	·5112	891·8560
17	·6101	858·8712	6	501·1288	·3899	17	15	·5095	892·3655
18	·6084	859·4796	7	560·5204	·3916	18	17	·5080	892·8735
17	·6066	860·0862	8	619·9138	·3934	17	16	·5063	893·3798
18	·6049	860·6911	9	679·3089	·3951	18	15	·5047	893·8845
	·6031				·3969			·5032	
17		861·2942	30	738·7058		17	17		894·3877
18	·6014	861·8956	1	798·1044	·3986	18	15	·5015	894·8892
17	·5996	862·4952	2	857·5048	·4004	17	16	·5000	895·3892
17	·5979	863·0931	3	916·9069	·4021	17	16	·4984	895·8876
17	·5962	863·6893	4	120976·3107	·4038	17	16	·4968	896·3844
18	·5945	864·2838	35	121035·7162	·4055	18	15	·4952	896·8796
17	·5927	864·8765	6	095·1235	·4073	17	17	·4937	897·3733
17	·5910	865·4675	7	154·5325	·4090	17	15	·4920	897·8653
17	·5893	866·0568	8	213·9432	·4107	17	15	·4905	898·3558
18	·5876	866·6444	9	273·3556	·4124	18	17	·4890	898·8448
	·5858				·4142			·4873	
17		867·2302	40	332·7698		17	15		899·3321
17	·5841	867·8143	1	392·1857	·4159	17	16	·4858	899·8179
17	·5824	868·3967	2	451·6033	·4176	17	15	·4842	900·3021
17	·5807	868·9774	3	511·0226	·4193	17	16	·4827	900·7848
17	·5790	869·5564	4	570·4436	·4210	17	15	·4811	901·2659
17	·5773	870·1337	45	629·8663	·4227	17	16	·4796	901·7455
17	·5756	870·7093	6	689·2907	·4244	17	16	·4780	902·2235
17	·5739	871·2832	7	748·7168	·4261	17	15	·4764	902·6999
17	·5722	871·8554	8	808·1446	·4278	17	15	·4749	903·1748
17	·5705	872·4259	9	867·5741	·4295	17	16	·4734	903·6482
	·5688				·4312			·4718	
17		872·9947	50	927·0053		17	16		904·1200
16	·5671	873·5618	1	121986·4382	·4329	16	14	·4702	904·5902
18	·5655	874·1273	2	122045·8727	·4345	18	16	·4688	905·0590
16	·5637	874·6910	3	105·3090	·4363	16	15	·4672	905·5262
18	·5621	875·2531	4	164·7469	·4379	18	16	·4657	905·9919
15	·5603	875·8134	55	224·1866	·4397	15	15	·4641	906·4560
18	·5588	876·3722	6	283·6278	·4412	18	15	·4626	906·9186
17	·5570	876·9292	7	343·0708	·4430	17	15	·4611	907·3797
16	·5553	877·4845	8	402·5155	·4447	16	16	·4596	907·8393
17	·5537	878·0382	9	461·9618	·4463	17	14	·4580	908·2973
	0·5520	161878·5902	60	122521·4098	59·4480			0·4566	161908·7539

′	−79°.	Diff.	Δ².	Δ².	Diff.	80°.	′	−80°.	Diff.	Δ²
		″			″	″		″	″	
0	122521·4098		16	16	0·4550	161908·7539	0	126091·2461		16
		59·4496							59·5450	
1	580·8594	·4513	17	15	·4535	909·2089	1	150·7911	·5465	15
2	640·3107	·4530	17	15	·4520	909·6624	2	210·3376	·5480	15
3	699·7637	·4546	16	16	·4504	910·1144	3	269·8856	·5496	16
4	759·2183	·4563	17	14	·4490	910·5648	4	329·4352	·5510	14
5	818·6746	·4579	16	15	·4475	911·0138	5	388·9862	·5525	15
6	878·1325	·4596	17	16	·4459	911·4613	6	448·5387	·5541	16
7	937·5921	·4613	17	14	·4445	911·9072	7	508·0928	·5555	14
8	122997·0534	·4629	16	15	·4430	912·3517	8	567·6483	·5570	15
9	123056·5163	·4645	16	15	·4415	912·7947	9	627·2053	·5585	15
10	115·9808	·4661	16	15	·4400	913·2362	10	686·7638	·5600	15
1	175·4469	·4678	17	15	·4385	913·6762	1	746·3238	·5615	15
2	234·9147	·4695	17	15	·4370	914·1147	2	805·8853	·5630	15
3	294·3842	·4710	15	15	·4355	914·5517	3	865·4483	·5645	15
4	353·8552	·4727	17	14	·4341	914·9872	4	925·0128	·5659	14
15	413·3279	·4744	17	15	·4326	915·4213	15	126984·5787	·5674	15
6	472·8023	·4759	15	15	·4311	915·8539	6	127044·1461	·5689	15
7	532·2782	·4776	17	15	·4296	916·2850.	7	103·7150	·5704	15
8	591·7558	·4792	16	14	·4282	916·7146	8	163·2854	·5718	14
9	651·2350.	·4808	16	15	·4267	917·1428	9	222·8572	·5733	15
20	710·7158	·4824	16	15	·4252	917·5695.	20	282·4305	·5748	15
1	770·1982	·4840	16	15	·4237	917·9947	1	342·0053	·5763	15
2	829·6822	·4857	17	14	·4223	918·4184	2	401·5816	·5777	14
3	889·1679	·4873	16	14	·4209	918·8407	3	461·1593	·5791	14
4	123948·6552	·4888	15	15	·4194	919·2616	4	520·7384	·5806	15
25	124008·1440	·4905	17	15	·4179	919·6810	25	580·3190	·5821	15
6	067·6345.	·4920	15	14	·4165	920·0989	6	639·9011	·5835	14
7	127·1265	·4937	17	14	·4151	920·5154	7	699·4846	·5849	14
8	186·6202	·4953	16	15	·4136	920·9305.	8	759·0695	·5864	15
9	246·1155	·4968	15	15	·4121	921·3441	9	818·6559	·5879	15
30	305·6123	·4985	17	14	·4107	921·7562	30	878·2438	·5893	14
1	365·1108	·5000	15	14	·4093	922·1669	1	937·8331	·5907	14
2	424·6108	·5016	16	15	·4078	922·5762	2	127997·4238	·5922	15
3	484·1124	·5032	16	14	·4064	922·9840	3	128057·0160	·5936	14
4	543·6156	·5048	16	14	·4050	923·3904	4	116·6096	·5950	14
35	603·1204	·5063	15	14	·4036	923·7954	35	176·2046	·5964	14
6	662·6267	·5080	17	15	·4021	924·1990	6	235·8010	·5979	15
7	722·1347	·5095	15	14	·4007	924·6011	7	295·3989	·5993	14
8	781·6442	·5110	15	14	·3993	925·0018	8	354·9982	·6007	14
9	841·1552	·5127	17	15	·3978	925·4011	9	414·5989	·6022	15
40	900·6679	·5142	15	13	·3965	925·7989	40	474·2011	·6035	13
1	124960·1821	·5158	16	15	·3950	926·1954	1	533·8046	·6050	15
2	125019·6979	·5173	15	14	·3936	926·5904	2	593·4096	·6064	14
3	079·2152	·5189	16	13	·3923	926·9840	3	653·0160	·6077	13
4	138·7341	·5204	15	15	·3908	927·3763	4	712·6237	·6092	15
45	198·2545	·5220	16	14	·3894	927·7671	45	772·2329	·6106	14
6	257·7765	·5236	16	14	·3880	928·1565.	6	831·8435	·6120	14
7	317·3001	·5251	15	14	·3866	928·5445.	7	891·4555	·6134	14
8	376·8252	·5266	15	14	·3852	928·9311	8	128951·0689	·6148	14
9	436·3518	·5282	16	14	·3838	929·3163	9	129010·6837	·6162	14
50	495·8800	·5298	16	13	·3825	929·7001	50	070·2999	·6175	13
1	555·4098	·5312	14	15	·3810	930·0826	1	129·9174	·6190	15
2	614·9410	·5328	16	13	·3797	930·4636	2	189·5364	·6203	13
3	674·4738	·5343	15	15	·3782	930·8433	3	249·1567	·6218	15
4	734·0081	·5359	16	13	·3769	931·2215	4	308·7785.	·6231	13
55	793·5440	·5374	15	13	·3756	931·5984	55	368·4016	·6244	13
6	853·0814	·5389	15	15	·3741	931·9740	6	428·0260	·6259	15
7	912·6203	·5404	15	13	·3728	932·3481	7	487·6519	·6272	13
8	125972·1607	·5420	16	14	·3714	932·7209	8	547·2791	·6286	14
9	126031·7027		14	14		933·0923	9	606·9077		
60	126091·2461	59·5434			0·3700	161933·4623	60	129666·5377	59·6300	

Δ°.	Diff.	81°.	′	−81°.	Diff.	Δ°.
	″	″		″	″	
13	0·3687	161933·4623	0	129666·5377	59·6313	13
14	·3673	933·8310	1	726·1690	·6327	14
14	·3659	934·1983	2	785·8017	·6341	14
13	·3646	·5642	3	845·4358	·6354	13
14	·3632	·9288	4	905·0712	·6368	14
13	·3619	935·2920	5	129964·7080	·6381	13
13	·3606	·6539	6	130024·3461	·6394	13
15	·3591	936·0145.	7	083·9855	·6409	15
12	·3579	·3736	8	143·6264	·6421	12
14	·3565	·7315.	9	203·2685	·6435	14
14	·3551	937·0880	10	262·9120	·6449	14
13	·3538	·4431	1	322·5569	·6462	13
13	·3525	·7969	2	382·2031	·6475	13
13	·3512	938·1494	3	441·8506	·6488	13
14	·3498	·5006	4	501·4994	·6502	14
13	·3485	·8504	15	561·1496	·6515	13
14	·3471	939·1989	6	620·8011	·6529	14
12	·3459	·5460	7	680·4540	·6541	12
14	·3445	·8919	8	740·1081	·6555	14
13	·3432	940·2364	9	799·7636	·6568	13
13	·3419	·5796	20	859·4204	·6581	13
13	·3406	·9215	1	919·0785.	·6594	13
13	·3393	941·2621	2	130978·7379	·6607	13
14	·3379	·6014	3	131038·3986	·6621	14
12	·3367	·9393	4	098·0607	·6633	12
14	·3353	942·2760	25	157·7240	·6647	14
12	·3341	·6113	6	217·3887	·6659	12
14	·3327	·9454	7	277·0546	·6673	14
12	·3315	943·2781	8	336·7219	·6685	12
13	·3302	·6096	9	396·3904	·6698	13
13	·3289	·9398	30	456·0602	·6711	13
14	·3275	944·2687	1	515·7313	·6725	14
12	·3263	·5962	2	575·4038	·6737	12
12	·3251	·9225	3	635·0775.	·6749	12
14	·3237	945·2476	4	694·7524	·6763	14
12	·3225	·5713	35	754·4287	·6775	12
13	·3212	·8938	6	814·1062	·6788	13
13	·3199	946·2150.	7	873·7850	·6801	13
12	·3187	·5349	8	933·4651	·6813	12
14	·3173	·8536	9	131993·1464	·6827	14
11	·3162	947·1709	40	132052·8291	·6838	11
14	·3148	·4871	1	112·5129	·6852	14
12	·3136	·8019	2	172·1981	·6864	12
13	·3123	948·1155	3	231·8845.	·6877	13
12	·3111	·4278	4	291·5722	·6889	12
12	·3099	·7389	45	351·2611	·6901	12
14	·3085	949·0488	6	410·9512	·6915	14
11	·3074	·3573	7	470·6427	·6926	11
13	·3061	·6647	8	530·3353	·6939	13
13	·3048	·9708	9	590·0292	·6952	13
12	·3036	950·2756	50	649·7244	·6964	12
12	·3024	·5792	1	709·4208	·6976	12
12	·3012	·8816	2	769·1184	·6988	12
13	·2999	951·1828	3	828·8172	·7001	13
13	·2986	·4827	4	888·5173	·7014	13
11	·2975	·7813	55	132948·2187	·7025	11
13	·2962	952·0788	6	133007·9212	·7038	13
12	·2950	·3750.	7	067·6250	·7050	12
12	·2938	·6700	8	127·3300	·7062	12
13	0·2925	·9638	9	187·0362	59·7075	13
		161953·2563	60	133246·7437		

Δ°.	Diff.	82°.
	″	″
11	0·2914	161953·2563
13	·2901	·5477
11	·2890	·8378
13	·2877	954·1268
12	·2865	·4145.
12	·2853	·7010
12	·2841	·9863
11	·2830	955·2704
13	·2817	·5534
12	·2805	·8351
11	·2794	956·1156
13	·2781	·3950.
11	·2770	·6731
12	·2758	·9501
12	·2746	957·2259
12	·2734	·5005
11	·2723	·7739
12	·2711	958·0462
12	·2699	·3173
11	·2688	·5872
12	·2676	·8560
12	·2664	959·1236
11	·2653	·3900
12	·2641	·6553
12	·2629	·9194
11	·2618	960·1823
11	·2607	·4441
12	·2595	·7048
12	·2583	·9643
10	·2573	961·2226
12	·2561	·4799
12	·2549	·7360
11	·2538	·9909
11	·2527	962·2447
11	·2516	·4974
12	·2504	·7490
11	·2493	·9994
11	·2482	963·2487
12	·2470	·4969
10	·2460	·7439
12	·2448	·9899
11	·2437	964·2347
11	·2426	·4784
10	·2416	·7210
12	·2404	·9626
11	·2393	965·2030
11	·2382	·4423
11	·2371	·6805.
11	·2360	·9176
11	·2349	966·1536
11	·2338	·3885
10	·2328	·6223
12	·2316	·8551
10	·2306	967·0867
11	·2295	·3173
10	·2285	·5468
12	·2273	·7753
10	·2263	968·0026
11	·2252	·2289
10	0·2242	·4541
		161968·6783

′	−82°.	Diff.	Δ².	Δ².	Diff.	83°.	′	−83°.	Diff.	Δ².
	″	″			″	″		″	″	
0	133246·7437	59·7086	11	12	0·2230	161968·6783	0	136831·3217	59·7770	12
1	306·4523	·7099	13	9	·2221	·9013	1	891·0987	·7779	9
2	366·1622	·7110	11	12	·2209	969·1234	2	136950·8766	·7791	12
3	425·8732	·7123	13	10	·2199	·3443	3	137010·6557	·7801	10
4	485·5855	·7135	12	10	·2189	·5642	4	070·4358	·7811	10
5	545·2990	·7147	12	11	·2178	·7831	5	130·2169	·7822	11
6	605·0137	·7159	12	11	·2167	970·0009	6	189·9991	·7833	11
7	664·7296	·7170	11	9	·2158	·2176	7	249·7824	·7842	9
8	724·4466	·7183	13	12	·2146	·4334	8	309·5666	·7854	12
9	784·1649	·7195	12	10	·2136	·6480	9	369·3520	·7864	10
10	843·8844	·7206	11	10	·2126	·8616	10	429·1384	·7874	10
1	903·6050	·7219	13	10	·2116	971·0742	1	488·9258	·7884	10
2	133963·3269	·7230	11	11	·2105	·2858	2	548·7142	·7895	11
3	134023·0499	·7242	12	10	·2095	·4963	3	608·5037	·7905	10
4	082·7741	·7254	12	10	·2085	·7058	4	668·2942	·7915	10
15	142·4995	·7266	12	11	·2074	·9143	15	728·0857	·7926	11
6	202·2261	·7277	11	10	·2064	972·1217	6	787·8783	·7936	10
7	261·9538	·7289	12	10	·2054	·3281	7	847·6719	·7946	10
8	321·6827	·7301	12	10	·2044	·5335	8	907·4665	·7956	10
9	381·4128	·7312	11	11	·2033	·7379	9	137967·2621	·7967	11
20	441·1440	·7324	12	9	·2024	·9412	20	138027·0588	·7976	9
1	500·8764	·7336	12	11	·2013	973·1436	1	086·8564	·7987	11
2	560·6100	·7347	11	10	·2003	·3449	2	146·6551	·7997	10
3	620·3447	·7359	12	10	·1993	·5452	3	206·4548	·8007	10
4	680·0806	·7371	12	9	·1984	·7445	4	266·2555	·8016	9
25	739·8177	·7382	11	11	·1973	·9429	25	326·0571	·8027	11
6	799·5559	·7393	11	10	·1963	974·1402	6	385·8598	·8037	10
7	859·2952	·7405	12	10	·1953	·3365	7	445·6635	·8047	10
8	919·0357	·7417	12	10	·1943	·5318	8	505·4682	·8057	10
9	134978·7774	·7427	10	9	·1934	·7261	9	565·2739	·8066	9
30	135038·5201	·7439	12	11	·1923	·9195	30	625·0805	·8077	11
1	098·2640	·7451	12	9	·1914	975·1118	1	684·8882	·8086	9
2	158·0091	·7462	11	10	·1904	·3032	2	744·6968	·8096	10
3	217·7553	·7473	11	10	·1894	·4936	3	804·5064	·8106	10
4	277·5026	·7484	11	10	·1884	·6830	4	864·3170	·8116	10
35	337·2510	·7496	12	10	·1874	·8714	35	924·1286	·8126	10
6	397·0006	·7507	11	9	·1865	976·0588	6	138983·9412	·8135	9
7	456·7513	·7518	11	10	·1855	·2453	7	139043·7547	·8145	10
8	516·5031	·7530	12	9	·1846	·4308	8	103·5692	·8154	9
9	576·2561	·7540	10	11	·1835	·6154	9	163·3846	·8165	11
40	636·0101	·7552	12	8	·1827	·7989	40	223·2011	·8173	8
1	695·7653	·7563	11	11	·1816	·9816	1	283·0184	·8184	11
2	755·5216	·7574	11	9	·1807	977·1632	2	342·8368	·8193	9
3	815·2790	·7584	10	10	·1797	·3439	3	402·6561	·8203	10
4	875·0374	·7596	12	9	·1788	·5236	4	462·4764	·8212	9
45	934·7970	·7607	11	9	·1779	·7024	45	522·2976	·8221	9
6	135994·5577	·7618	11	11	·1768	·8803	6	582·1197	·8232	11
7	136054·3195	·7629	11	8	·1760	978·0571	7	641·9429	·8240	8
8	114·0824	·7640	11	10	·1750	·2331	8	701·7669	·8250	10
9	173·8464	·7651	11	9	·1741	·4081	9	761·5919	·8259	9
50	233·6115	·7662	11	10	·1731	·5822	50	821·4178	·8269	10
1	293·3777	·7672	10	9	·1722	·7553	1	881·2447	·8278	9
2	353·1449	·7684	12	10	·1712	·9275	2	139941·0725	·8288	10
3	412·9133	·7694	10	9	·1703	979·0987	3	140000·9013	·8297	9
4	472·6827	·7705	11	9	·1694	·2690	4	060·7310	·8306	9
55	532·4532	·7715	10	9	·1685	·4384	55	120·5616	·8315	9
6	592·2247	·7727	12	9	·1676	·6069	6	180·3931	·8324	9
7	651·9974	·7737	10	10	·1666	·7745	7	240·2255	·8334	10
8	711·7711	·7748	11	9	·1657	·9411	8	300·0589	·8343	9
9	771·5459					980·1068	9	359·8932		
60	136831·3217	59·7758	10	9	0·1648	161980·2716	60	140419·7284	59·8352	9

Δ².	Diff.	84°.	′	−84°.	Diff.	Δ².	Δ².	Diff.	85°.
	″	″		″	″			″	′
9	0·1639	161980·2716	0	140419·7284	59·8361	9	75	0·11378	161988·58119
9	·1630	·4355·	1	479·5645	·8370	9	75	·11303	·69497
10	·1620	·5985·	2	539·4015	·8380	10	77	·11226	·80800
8	·1612	·7605	3	599·2395·	·8388	8	75	·11151	·92096
9	·1603	·9217	4	659·0783	·8397	9	75	·11076	989·03177
10	·1593	981·0820	5	718·9180	·8407	10	74	·11002	·14253
8	·1585	·2413	6	778·7587	·8415	8	75	·10927	·25325
9	·1576	·3998	7	838·6002	·8424	9	75	·10852	·36182
9	·1567	·5574	8	898·4426	·8433	9	73	·10779	·47034
9	·1558	·7141	9	140958·2859	·8442	9	74	·10705	·57813
9	·1549	·8699	10	141018·1301	·8451	9	74	·10631	·68518
9	·1540	982·0248	1	077·9752	·8460	9	73	·10558	·79149
9	·1531	·1788	2	137·8212	·8469	9	73	·10485	·89707
8	·1523	·3319	3	197·6681	·8477	8	73	·10412	990·00192
9	·1514	·4842	4	257·5158	·8486	9	72	·10340	·10604
9	·1505	·6356	15	317·3644	·8495	9	73	·10267	·20944
9	·1496	·7861	6	377·2139	·8504	9	71	·10196	·31211
8	·1488	·9357	7	437·0643	·8512	8	73	·10123	·41407
9	·1479	983·0845·	8	496·9155	·8521	9	71	·10052	·51530
9	·1470	·2324	9	556·7676	·8530	9	71	·09981	·61582
8	·1462	·3794	20	616·6206	·8538	8	71	·09910	·71563
9	·1453	·5256	1	676·4744	·8547	9	71	·09839	·81473
85	·14445	·6709	2	736·3291	·85555	85	70	·09769	·91312
84	·14361	·81535·	3	796·18465	·85639	84	71	·09698	991·01081
86	·14275	·95896	4	856·04104	·85725	86	69	·09629	·10779
85	·14190	984·10171	25	915·89829	·85810	85	71	·09558	·20408
84	·14106	·24361	6	141975·75639	·85894	84	68	·09490	·29966
85	·14021	·38467	7	142035·61533	·85979	85	70	·09420	·39456
84	·13937	·52488	8	095·47512	·86063	84	70	·09350	·48876
83	·13854	·66425	9	155·33575·	·86146	83	67	·09283	·58226
85	·13769	·80279	30	215·19721	·86231	85	69	·09214	·67509
83	·13686	·94048	1	275·05952	·86314	83	69	·09145	·76723
82	·13604	985·07734	2	334·92266	·86396	82	67	·09078	·85868
84	·13520	·21338	3	394·78662	·86480	84	68	·09010	·94946
83	·13437	·34858	4	454·65142	·86563	83	68	·08942	992·03956
81	·13356	·48295	35	514·51705·	·86644	81	67	·08875	·12898
83	·13273	·61651	6	574·38349	·86727	83	66	·08809	·21773
82	·13191	·74924	7	634·25076	·86809	82	68	·08741	·30582
82	·13109	·88115·	8	694·11885	·86891	82	65	·08676	·39323
80	·13029	986·01224	9	753·98776	·86971	80	68	·08608	·47999
82	·12947	·14253	40	813·85747	·87053	82	65	·08543	·56607
81	·12866	·27200	1	873·72800	·87134	81	65	·08478	·65150
80	·12786	·40066	2	933·59934	·87214	80	66	·08412	·73628
81	·12705	·52852	3	142993·47148	·87295	81	65	·08347	·82040
80	·12625	·65557	4	143053·34443	·87375	80	65	·08282	·90387
80	·12545	·78182	45	113·21818	·87455	80	65	·08217	·98669
79	·12466	·90727	6	173·09273	·87534	79	65	·08152	993·06886
79	·12387	987·03193	7	232·96807	·87613	79	63	·08089	·15038
80	·12307	·15580	8	292·84420	·87693	80	64	·08025	·23127
79	·12228	·27887	9	352·72113	·87772	79	65	·07960	·31152
78	·12150	·40115	50	412·59885·	·87850	78	62	·07898	·39112
78	·12072	·52265	1	472·47735·	·87928	78	63	·07835	·47010
79	·11993	·64337	2	532·35663	·88007	79	64	·07771	·54845
77	·11916	·76330	3	592·23670	·88084	77	62	·07709	·62616
78	·11838	·88246	4	652·11754	·88162	78	62	·07647	·70325
78	·11760	988·00084	55	711·99916	·88240	78	63	·07584	·77972
76	·11684	·11844	6	771·88156	·88316	76	62	·07522	·85556
77	·11607	·23528	7	831·76472	·88393	77	61	·07461	·93078
76	·11531	·35135	8	891·64865·	·88469	76	61	·07400	994·00539
78	0·11453	·46666	9	143951·53334	59·88547	78	62	0·07338	·07939
		161988·58119	60	144011·41881					161994·15277

′	−85°.	Diff.	Δ².	Δ².	Diff.	86°.	′	−86°.	Diff.	Δ².
	″	″			″	″		″	″	
0	144011·41881		75	61	0·07277	161994·15277	0	147605·84723		61
1	071·30503	59·88622	75	60	·07217	·22554	1	665·77446	59·92723	60
2	131·19200	·88697	77	60	·07157	·29771	2	725·70229	·92783	60
3	191·07974	·88774	75	61	·07096	·36928	3	785·63072	·92843	61
4	250·96823	·88849	75	59	·07037	·44024	4	845·55976	·92904	59
5	310·85747	·88924	74	61	·06976	·51061	5	905·48939	·92963	61
6	370·74745	·88998	75	59	·06917	·58037	6	147965·41963	·93024	59
7	430·63818	·89073	75	59	·06858	·64954	7	148025·35046	·93083	59
8	490·52966	·89148	73	57	·06801	·71812	8	085·28188	·93142	59
9	550·42187	·89221	74	60	·06741	·78613	9	145·21387	·93199	57
		·89295							·93259	60
10	610·31482	·89369	74	58	·06683	·85354	10	205·14646	·93317	58
1	670·20851	·89442	73	59	·06624	·92037	1	265·07963	·93376	59
2	730·10293	·89515	73	57	·06567	·98661	2	325·01339	·93433	57
3	789·99808	·89588	73	58	·06509	995·05228	3	384·94772	·93491	58
4	849·89396	·89660	72	57	·06452	·11737	4	444·88263	·93548	57
15	909·79056	·89733	73	57	·06395	·18189	15	504·81811	·93605	57
6	144969·68789	·89804	71	58	·06337	·24584	6	564·75416	·93663	58
7	145029·58593	·89877	73	55	·06282	·30921	7	624·69079	·93718	55
8	089·48470	·89948	71	57	·06225	·37203	8	684·62797	·93775	57
9	149·38418	·90019	71	56	·06169	·43428	9	744·56572	·93831	56
20	209·28437	·90090	71	56	·06113	·49597	20	804·50403	·93887	56
1	269·18527	·90161	71	55	·06058	·55710	1	864·44290	·93942	55
2	329·08688	·90231	70	56	·06002	·61768	2	924·38232	·93998	56
3	388·98919	·90302	71	55	·05947	·67770	3	148984·32230	·94053	55
4	448·89221	·90371	69	54	·05893	·73717	4	149044·26283	·94107	54
25	508·79592	·90442	71	55	·05838	·79610	25	104·20390	·94162	55
6	568·70034	·90510	68	55	·05783	·85448	6	164·14552	·94217	55
7	628·60544	·90580	70	53	·05730	·91231	7	224·08769	·94270	53
8	688·51124	·90650	70	54	·05676	·96961	8	284·03039	·94324	54
9	748·41774	·90717	67	54	·05622	996·02637	9	343·97363	·94378	54
30	808·32491	·90786	69	53	·05569	·08259	30	403·91741	·9443I	53
1	868·23277	·90855	69	53	·05516	·13828	1	463·86172	·94484	53
2	928·14132	·90922	67	53	·05463	·19344	2	523·80656	·94537	53
3	145988·05054	·90990	68	52	·05411	·24807	3	583·75193	·94589	52
4	146047·96044	·91058	68	53	·05358	·30218	4	643·69782	·94642	53
35	107·87102	·91125	67	51	·05307	·35576	35	703·64424	·94693	51
6	167·78227	·91191	66	53	·05254	·40883	6	763·59117	·94746	53
7	227·69418	·91259	68	51	·05203	·46137	7	823·53863	·94797	51
8	287·60677	·91324	65	51	·05152	·51340	8	883·48660	·94848	51
9	347·52001	·91392	68	51	·05101	·56492	9	149943·43508	·94899	51
40	407·43393	·91457	65	51	·05050	·61593	40	150003·38407	·94950	51
1	467·34850.	·91522	65	50	·05000	·66643	1	063·33357	·95000	50
2	527·26372	·91588	66	50	·04950	·71643	2	123·28357	·95050	50
3	587·17960	·91653	65	51	·04899	·76593	3	183·23407	·95101	51
4	647·09613	·91718	65	49	·04850	·81492	4	243·18508	·95150	49
45	707·01331	·91783	65	50	·04800	·86342	45	303·13658	·95200	50
6	766·93114	·91848	65	49	·04751	·91142	6	363·08858	·95249	49
7	826·84962	·91911	63	49	·04702	·95893	7	423·04107	·95298	49
8	886·76873	·91975	64	48	·04654	997·00595	8	482·99405.	·95346	48
9	146946·68848	·92040	65	49	·04605	·05249	9	542·94751	·95395	49
50	147006·60888	·92102	62	48	·04557	·09854	50	602·90146	·95443	48
1	066·52990	·92165	63	49	·04508	·14411	1	662·85589	·95492	49
2	126·45155	·92229	64	47	·04461	·18919	2	722·81081	·95539	47
3	186·37384	·92291	62	47	·04414	·23380	3	782·76620	·95586	47
4	246·29675.	·92353	62	48	·04366	·27794	4	842·72206	·95634	48
55	306·22028	·92416	63	46	·04320	·32160	55	902·67840	·95680	46
6	366·14444	·92478	62	47	·04273	·36480	6	150962·63520	·95727	47
7	426·06922	·92539	61	47	·04226	·40753	7	151022·59247	·95774	47
8	485·99461	·92600	61	46	·04180	·44979	8	082·55021	·95820	46
9	545·92061		62	45	·04135	·49159	9	142·50841		45
60	147605·84723	59·92662				161997·53294	60	151202·46706	59·95865	

Δ²	Diff.	87°.	′	−87°.	Diff.	Δ².	Δ².	Diff.	88°.
	″	″		″	″			″	″
47	0·04088	161997·53294	0	151202·46706	59·95912	47	30	0·01813	161999·26896
45	·04043	·57382	1	262·42618	·95957	45	31	·01782	·28709
45	·03998	·61425	2	322·38575	·96002	45	30	·01752	·30491
44	·03954	·65423	3	382·34577	·96046	44	30	·01722	·32243
46	·03908	·69377	4	442·30623	·96092	46	29	·01693	·33965
44	·03864	·73285	5	502·26715	·96136	44	29	·01664	·35658
44	·03820	·77149	6	562·22851	·96180	44	29	·01635	·37322
44	·03776	·80969	7	622·19031	·96224	44	29	·01606	·38957
44	·03732	·84745	8	682·15255	·96268	44	28	·01578	·40563
43	·03689	·88477	9	742·11523	·96311	43	28	·01550	·42141
43	·03646	·92166	10	802·07834	·96354	43	28	·01522	·43691
43	·03603	·95812	1	862·04188	·96397	43	28	·01494	·45213
43	·03560	·99415	2	922·00585	·96440	43	28	·01466	·46707
42	·03518	998·02975	3	151981·97025	·96482	42	26	·01440	·48173
42	·03476	·06493	4	152041·93507	·96524	42	28	·01412	·49613
42	·03434	·09969	15	101·90031	·96566	42	26	·01386	·51025
42	·03392	·13403	6	161·86597	·96608	42	26	·01360	·52411
41	·03351	·16795	7	221·83205	·96649	41	27	·01333	·53771
41	·03310	·20146	8	281·79854	·96690	41	25	·01308	·55104
41	·03269	·23456	9	341·76544	·96731	41	26	·01282	·56412
40	·03229	·26725	20	401·73275	·96771	40	26	·01256	·57694
41	·03188	·29954	1	461·70046	·96812	41	24	·01232	·58950
40	·03148	·33142	2	521·66858	·96852	40	26	·01206	·60182
40	·03108	·36290	3	581·63710	·96892	40	24	·01182	·61388
40	·03068	·39398	4	641·60602	·96932	40	24	·01158	·62570
39	·03029	·42466	25	701·57534	·96971	39	25	·01133	·63728
38	·02991	·45495	6	761·54505	·97009	38	23	·01110	·64861
40	·02951	·48486	7	821·51514	·97049	40	24	·01086	·65971
38	·02913	·51437	8	881·48563	·97087	38	24	·01062	·67057
39	·02874	·54350	9	152941·45650	·97126	39	23	·01039	·68119
38	·02836	·57224	30	153001·42776	·97164	38	22	·01017	·69158
37	·02799	·60060	1	061·39940	·97201	37	23	·00994	·70175
38	·02761	·62859	2	121·37141	·97239	38	22	·00972	·71169
37	·02724	·65620	3	181·34380	·97276	37	23	·00949	·72141
38	·02686	·68344	4	241·31656	·97314	38	21	·00928	·73090
36	·02650	·71030	35	301·28970	·97350	36	21	·00907	·74018
37	·02613	·73680	6	361·26320	·97387	37	22	·00885	·74925
36	·02577	·76293	7	421·23707	·97423	36	22	·00863	·75810
36	·02541	·78870	8	481·21130	·97459	36	20	·00843	·76673
36	·02505	·81411	9	541·18589	·97495	36	20	·00823	·77516
35	·02470	·83916	40	601·16084	·97530	35	21	·00802	·78339
35	·02435	·86386	1	661·13614	·97565	35	20	·00782	·79141
36	·02399	·88821	2	721·11179	·97601	36	20	·00762	·79923
35	·02364	·91220	3	781·08780	·97636	35	19	·00743	·80685
34	·02330	·93584	4	841·06416	·97670	34	19	·00724	·81428
34	·02296	·95914	45	901·04086	·97704	34	20	·00704	·82152
34	·02262	·98210	6	153961·01790	·97738	34	18	·00686	·82856
34	·02228	999·00472	7	154020·99528	·97772	34	19	·00667	·83542
33	·02195	·02700	8	080·97300	·97805	33	18	·00649	·84209
34	·02161	·04895	9	140·95105	·97839	34	18	·00631	·84858
33	·02128	·07056	50	200·92944	·97872	33	18	·00613	·85489
32	·02096	·09184	1	260·90816	·97904	32	18	·00595	·86102
33	·02063	·11280	2	320·88720	·97937	33	17	·00578	·86697
32	·02031	·13343	3	380·86657	·97969	32	16	·00562	·87275
32	·01999	·15374	4	440·84626	·98001	32	18	·00544	·87837
32	·01967	·17373	55	500·82627	·98033	32	16	·00528	·88381
31	·01936	·19340	6	560·80660	·98064	31	16	·00512	·88900
32	·01904	·21276	7	620·78724	·98096	32	16	·00496	·89421
31	·01873	·23180	8	680·76820	·98127	31	16	·00480	·89917
30	0·01843	·25053	9	740·74947	59·98157	30	15	0·00465	·90397
		161999·26896	60	154800·73104					161999·90862

−73°.	Diff.	Δ¹.	Δ².	Diff.	74°.	′	−74°.	Diff.	Δ¹.
″	″			″	″		″	″	
101247·0035.	58·6904	25	25	1·1609	161627·1429	0	104772·8571	58·8391	25
305·6939	·6930	26	23	·1586	628·3038	1	831·6962	·8414	23
364·3869	·6955	25	25	·1561	629·4624	2	890·5376	·8439	25
423·0824	·6980	25	23	·1538	630·6185	3	104949·3815.	·8462	23
481·7804	·7006	26	25	·1513	631·7723	4	105008·2277	·8487	25
540·4810	·7032	26	23	·1490	632·9236	5	067·0764	·8510	23
599·1842	·7057	25	25	·1465	634·0726	6	125·9274	·8535	25
657·8899	·7082	25	23	·1442	635·2191	7	184·7809	·8558	23
716·5981	·7107	25	24	·1418	636·3633	8	243·6367	·8582	24
775·3088	·7133	26	24	·1394	637·5051	9	302·4949	·8606	24
834·0221	·7158	25	23	·1371	638·6445.	10	361·3555	·8629	23
892·7379	·7183	25	25	·1346	639·7816	1	420·2184	·8654	25
101951·4562	·7208	25	23	·1323	640·9162	2	479·0838	·8677	23
102010·1770	·7234	26	24	·1299	642·0485.	3	537·9515	·8701	24
068·9004	·7259	25	24	·1275	643·1784	4	596·8216	·8725	24
127·6263	·7284	25	23	·1252	644·3059	15	655·6941	·8748	23
186·3547	·7309	25	24	·1228	645·4311	6	714·5689	·8772	24
245·0856	·7334	26	24	·1204	646·5539	7	773·4461	·8796	24
303·8190	·7360	24	23	·1181	647·6743	8	832·3257	·8819	23
362·5550.	·7384		24	·1157	648·7924	9	891·2076	·8843	24
421·2934	·7409	25	24	·1133	649·9081	20	105950·0919	·8867	24
480·0343	·7435	26	23	·1110	651·0214	1	106008·9786	·8890	23
538·7778	·7459	24	23	·1087	652·1324	2	067·8676	·8913	23
597·5237	·7484	25	25	·1062	653·2411	3	126·7589	·8938	25
656·2721	·7509	25	22	·1040	654·3473	4	185·6527	·8960	22
715·0230	·7535	26	24	·1016	655·4513	25	244·5487	·8984	24
773·7765.	·7559	24	23	·0993	656·5529	6	303·4471	·9007	23
832·5324	·7583	24	24	·0969	657·6522	7	362·3478	·9031	24
891·2907	·7609	26	23	·0946	658·7491	8	421·2509	·9054	23
102950·0516	·7634	25	24	·0922	659·8437	9	480·1563	·9078	24
103008·8150.	·7658	24	23	·0899	660·9359	30	539·0641	·9101	23
067·5808	·7683	25	23	·0876	662·0258	1	597·9742	·9124	23
126·3491	·7708	25	23	·0853	663·1134	2	656·8866	·9147	23
185·1199	·7732	24	23	·0830	664·1987	3	715·8013	·9170	23
243·8931	·7758	26	24	·0806	665·2817	4	774·7183	·9194	24
302·6689	·7782	24	23	·0783	666·3623	35	833·6377	·9217	23
361·4471	·7806	24	24	·0759	667·4406	6	892·5594	·9241	24
420·2277	·7831	25	22	·0737	668·5165	7	106951·4835.	·9263	22
479·0108	·7856	25	23	·0714	669·5902	8	107010·4098	·9286	23
537·7964	·7880	24	24	·0690	670·6616	9	069·3384	·9310	24
596·5844	·7905	25	23	·0667	671·7306	40	128·2694	·9333	23
655·3749	·7929	24	22	·0645	672·7973	1	187·2027	·9355	22
714·1678	·7954	25	24	·0621	673·8618	2	246·1382	·9379	24
772·9632	·7978	24	23	·0598	674·9239	3	305·0761	·9402	23
831·7610	·8003	25	23	·0575	675·9837	4	364·0163	·9425	23
890·5613	·8027	24	22	·0553	677·0412	45	422·9588	·9447	22
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066·9768	·8100	24	24	·0483	680·2001	8	599·7999	·9517	24
125·7868	·8125	25	22	·0461	681·2484	9	658·7516	·9539	22
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419·8734	·8246	24	23	·0347	686·4560	4	107953·5440	·9653	23
478·6980	·8270	24	23	·0324	687·4907	55	108012·5093	·9676	23
537·5250.	·8294	24	23	·0301	688·5231	6	071·4769	·9699	23
596·3544	·8318	24	22	·0279	689·5532	7	130·4468	·9721	22
655·1862	·8343	25	23	·0256	690·5811	8	189·4189	·9744	23
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"Further Observations on Nova Persei. No. 4." By Sir NORMAN LOCKYER, K.C.B., F.R.S. Received October 10, 1901.

The last paper* contained an account of the observations of the Nova made at Kensington between March 25 and May 7. The observations are, in the present paper, brought up to September 30. Between June 18 and August 8 no work was done on the Nova, owing chiefly to the interference of buildings and twilight.

* 'Roy. Soc. Proc.,' vol. 68, p. 399.

Magnitude.

The magnitude has been estimated on sixteen evenings. These seem to afford sufficient evidence that since the beginning of May the star has decreased in magnitude from about 5·7 to 6·7; further, the short variations previously recorded apparently no longer exist, as the estimated magnitudes on eleven nights since the end of August only vary between 6·5 and 6·8.

Photographs of the region about the Nova were taken with the 6-inch Dallmeyer doublet on the evenings of August 25 and September 11, 12, and 18. From these it has been ascertained that its magnitude relatively to those of the surrounding stars is greater photographically than visually.

Visual Spectrum.

The spectrum has been observed with a McClean direct-vision spectroscope on the evenings of August 8, 13, 17, 20, 22, 24, and September 11, 12, 18. The line in the position of the chief nebular line at λ 5007 has always been noted as being the strongest, Hβ and the line at λ 4959 being also present, but comparatively much weaker. Fairly bright lines near λ 472 and the region of Hγ have also been recorded. Traces of a few lines less refrangible than λ 5007 have been glimpsed, but no determinations of their wave-lengths have been made. No lines have been observed in the yellow or red regions of the spectrum.

Photographic Spectrum.

Photographs have been taken on the evenings of August 9, 15, 17, 21, 22, 23, 24, 26, September 3, 5, 9, 10, 11, 12, 18, 21, 23, 25, 26, with the 9-inch prismatic reflector, the Nova being now far too faint for the utilisation of the 6-inch objective prism, and, until quite recently, in such a position as to make the 30-inch reflector unavailable. These photographs show little or no variation amongst themselves either in the number, position, or relative intensities of the lines. The scale of the photographs is such that the distance between Hβ and Hε is about 0·9 cm. The wave-lengths of the lines have been determined from the best photograph (August 26) by means of an interpolation curve. The presence in the Nova spectrum of some of the hydrogen lines and the helium line λ 4471 was established by direct comparison with the spectra of other stars photographed with the same instrument. These lines were used, together with the 5007 line (the identity of which with the strongest nebula line was assumed), as fiducial lines for the construction of the interpolation curve. The remaining lines were then measured and their wave-lengths read off from the curve. The intensities of the lines as they appear on the plate were also noted.

The spectrum has undergone great modification since the last photographs were taken at Kensington in March and April. The lines are about the same in number and position, but their nature and relative intensities have vastly changed. In the latter part of March and the early part of April the lines were generally broad and ill-defined. They are now narrower, and with better defined edges. The greatest change noticeable in the spectrum is with respect to the relative weakening of the hydrogen lines generally and the alteration in relative intensity amongst some of them. In the earlier photographs the hydrogen lines were very prominent, and the individual members of the series gradually weakened as the ultra-violet part of the spectrum was approached. In the latest photographs they appear of quite secondary importance. Hβ, Hγ, and Hδ are all present, but occur only as comparatively weak lines, especially the latter two. With regard to Hϵ, apparently the only other hydrogen line shown, the case is different. The line at or near the position of Hϵ is now about the second strongest line in the whole photographic spectrum, and many times stronger than either Hδ, Hγ, or Hβ. With this fact in view, it may be suggested that this strong line is possibly not wholly due to hydrogen, but is mainly a new line of unknown origin, which happens to fall exactly on, or very near to, the position of Hϵ. The line appears to be of much the same nature as the stronger adjacent line at λ 3868. The following table gives the wave-lengths and intensities of the lines visible in the photographs:—

$\lambda\lambda$.	Int. (max. = 10).	Remarks.
3868	10	Strong line in spectrum of planetary nebulæ.
3970	8	Probably not wholly due to hydrogen (Hϵ), intensity abnormal.
4102	2	Hδ.
4341	2	Hγ.
4364	7	
4471	1	Helium.
4636	3	
4684	2	Probably identical with 4687 of ζ Puppis and Orion stars.
4720	6	
4808	<1	
4862	3	Hβ.
4959	2	Apparently identical with second nebula line.
5007	4	„ „ strongest „

In addition to the lines in the above table, six of the photographs including that of August 26, give indications of the presence of a line in the extreme ultra-violet. Its wave-length could not be obtained

with any degree of accuracy owing to lack of comparison photographs showing lines in the same part of the spectrum, but it is probably identical with the line at λ 342 which von Gothard has independently recorded.*

The enhanced lines of iron, magnesium, &c., which were such a conspicuous feature of the earlier photographs of the Nova spectrum, have now entirely disappeared, and the probability is that the bright lines of the present spectrum other than those of hydrogen and helium belong to gases the terrestrial equivalents of which have not been found. It may be mentioned, however, that in their paper "On the Spectrum of the more Volatile Gases of Air,"† Professors Liveing and Dewar record weak lines at λλ $\frac{4363}{4365}$ and 4636 which may possibly have the same chemical origin as the Nova lines 4364 and 4636.

As there is no indication of the new lines forming a series similar to those given by hydrogen and helium, there is probably more than one gas involved.

Characteristics of the Hydrogen and other Lines.

In the series of photographs under discussion, the hydrogen lines no longer exhibit the curious structure described in previous communications, but are much fainter and rather narrower and devoid of any apparent differences in density. Some of the bright lines—notably λ 3868 and λ 3970—are of about the same width as the adjacent hydrogen lines were in the earlier photographs, and show a structure somewhat similar to that illustrated in a previous note.‡

The lines in question appear as triplets, and in each case the most refrangible member is slightly brighter than the others. The lines at λ 4364 and λ 4720 are narrower and less intense than those just mentioned, and put on the appearance of doubles, the brighter members being still on the more refrangible side.

Appearance of the Star.

Visual examination of the star under high powers shows that the Nova has a decidedly larger disc than is possessed by neighbouring stars of similar magnitude. Photographs of the region of the Nova taken on the nights of September 11 and 12, 1901, with a Dallmeyer rectilinear objective of 6 inches aperture and focal length of 4 feet 6 inches, show the penumbral aureole very clearly. It has a fairly definite outline, and is altogether different in character from the

* 'Astro. Nach.,' No. 3738.
† 'Roy. Soc. Proc.,' vol. 67, p. 467.
‡ 'Roy. Soc. Proc.,' vol. 68, p. 234.

images of neighbouring stars of equal magnitude. This peculiarity of the Nova's disc was first remarked by Flammarion and Antoniadi, and later by Max Wolf, Kostinsky, and von Gothard. It owes its origin probably to the exceptionally strong ultra-violet rays emitted by the Nova, which are not brought to the focus for which the objective is corrected.

The recent photographs have been taken by Mr. Butler and Mr. Rolston. The visual observations have chiefly been made by Messrs. Fowler and Butler. Mr. Baxandall has undertaken the reduction to wave-lengths and the discussion of the lines in the photographic spectrum, while Dr. Lockyer and Mr. Baxandall have assisted in the preparation of the present paper.

"Total Solar Eclipse of 1901 May 17–18. Preliminary Report of the Observations made at Ayer Karoe, Sawah Loento, Sumatra." By H. F. NEWALL, M.A. Received October 30,—Read at Joint Meeting of the Royal and Royal Astronomical Societies, October 31, 1901.

This expedition was one of those organised by the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society, funds being provided from a grant made by the Government Grant Committee.

It was originally contemplated that the party should consist of Professor H. H. Turner and myself, and that we should occupy a station inland in Sumatra; but when the former found himself unable to join in the expedition, it was decided not to appoint another observer in his stead, nor to fix upon the station to be occupied until there was an opportunity of learning about local conditions on the spot.

The expedition was to go to Padang, on the West Coast of Sumatra, and to this port I travelled in company with Mr. F. W. Dyson, who went out from the Royal Observatory, Greenwich. It was decided that we should travel out together, prepared either to join forces at one and the same camp, or to form two camps separated by a considerable distance, and our ultimate decision was to depend upon information which we expected to get from the Dutch authorities.

I had communicated with Major Muller, the Chief of the Survey

Department at Batavia, with reference to a possible site for a camp at or near Solok (a station about 40 miles inland on the State Railway), or still further eastwards near the Oembilien coalfields; for it seemed that a station on the east side of the Barisan Mountains would be more likely to have favourable conditions of weather in May than stations on the west side, an opinion based on careful study of both Dr. van der Stok's large work on 'Wind, Weather, &c., in the Indian Archipelago' (Batavia, 1897), and also of the summary published by the Dutch Indies Scientific Society over the names of Major Muller and Dr. Figee, for the information of observers. I may say at once that the reality proved that this opinion, based on averages, was not worth much, for the local conditions seemed, at any rate in 1901, to play a comparatively small part in the determination of weather.

The route chosen for getting to Sumatra was that *vid* Genoa, and thence by Dutch Royal Mail steamship *vid* Red Sea direct to Padang, and we are indebted to the Nederland Steamship Company for considerable reduction in fares in consideration of the scientific object of the journey. Mr. Dyson and I and my wife left Charing Cross on March 12, and travelled across the Continent together, and were joined at Genoa by Mr. J. J. Atkinson, who had generously volunteered to go with the expedition to Sumatra to assist in the observations and preparations, as he had done in the previous year with the Astronomer Royal's party in Portugal. We went on board the Dutch mail-steamer "Koningin Regentes," and sailed from Genoa on March 14. The advantages of the route were that it took us in the shortest possible time direct to our port, Padang, lying on the track of the moon's shadow, and gave us the opportunity of making the acquaintance of the Dutch astronomers, who, as we had learnt from Professor Bakhuysen, the President of the Committee charged with organising the Dutch expedition, were going out on the "Koningin Regentes"; and, furthermore, as the boat called at Southampton, it was possible to take the instruments, huts, &c., on the same boat as we ourselves travelled by without transhipment.

Mr. Dyson and I had seen to sending our cases to Southampton, and had personally put some of the more delicate instruments on board the "Koningin Regentes" on March 4. The large 4-prism spectrograph, which I was to use at the eclipse, was kept in use at Cambridge for observations of the Nova Persei until the day of my departure from Cambridge, March 11, when it was dismounted and packed; it was then taken across the Continent, and put on board the "Koningin Regentes" at Genoa. The Dutch observers, Professor W. H. Julius, Professor A. A. Nyland, and Mr. Wilterdinck, also joined the boat at Genoa, as well as a party from the Massachussetts Institute of Technology, Boston, consisting of Professor A. E. Burton, Professor Hosmer, Professor Harrison W. Smith, and Mr. Matthes.

On arrival at Padang on Saturday, April 6, we made the acquaintance of the Governor of the West Coast of Sumatra and of Major Muller, head of the Survey Department, and Mr. Delprat, the head of the State Railways. The Governor received us on the following Monday morning, and we recall with great pleasure the personal courtesy and friendly helpfulness which he at once extended to us. Nothing could exceed the kindness and consideration which we experienced throughout our stay in the island from the Dutch authorities with whom it was our good fortune to come in contact. I may here add that I took the opportunity, which was afforded me by a visit to Java after the eclipse, to express to the Governor-General of the Dutch Indies the informal thanks of the English observers for the generous assistance which had been given to them in their expedition.

We were indebted to Professor Bakhuysen, the President of the Dutch Committee, for several sets of maps of the admirable survey of the West Coast of Sumatra. The local authorities at Padang added to our obligations by presenting us with free passes for ourselves and freight over all the railway system on the West Coast.

The Governor of the West Coast arranged that Mr. Dyson and Mr. Atkinson should make use of his steam launch to inspect possible sites for a camp on the coast in Trusan Bay, and also on an island 6 miles from the coast opposite Painan. Mr. Delprat was able to give me information and much kind assistance in the matter of sites inland near the Oembilien coalfield, and I at once set off to Sawah Loento with introductions to Mr. van Lessen, the Chief Engineer of the mines.

Thus it came about that when Mr. Dyson and I met again at Padang on the following Thursday, April 11, we had gained such information that we were able to decide at once that we should occupy separate camps (i) Mr. Dyson, together with Mr. Atkinson, on the island Aoer Gadang, assisted by H.M.S. "Pigmy," a gunboat commanded by Lieutenant-Commander Oldham, R.N., which, in response to an application from the Royal Society, had been told off by the Admiralty to render assistance to the observers; and (ii) myself inland, on tolerably high ground, not far from Sawah Loento, the last station on the railway, at the mouth of the Oembilien coal mines, and thus quite on the east side of the Barisan Range. Our stations were thus the most widely separated in Sumatra, Mr. Dyson being at the west end of the line, and the first of the Sumatran observers to be immersed in the moon's shadow, whilst I was furthest inland at the east end of the line.

The rest of this report deals with my own experiences and observations.

It was with regret that I had to decline the invitation of the Boston

observers to join forces with them; they had chosen an excellent site on a ridge to the south of Sawah Loento, but it was at a considerable distance from the living quarters, and it seemed to me that in that tropical climate we could not afford to spend much of our forces in walking to and fro, for the somewhat extensive programme of observations would require much preparation. Under the guidance of Mr. van Lessen, the Chief Engineer at the mines, an excellent site was found on high ground above the mines to the N.W. of Sawah Loento; and Mr. van Lessen was good enough to put at my disposal a house close to it, which had recently been built for the use of officers of the mines, but which had not yet been occupied. The house was close to four others in which mine-viewers were living, and, moreover, other houses were being built in their neighbourhood. Hence the conveniences were in every respect very great, for the conditions implied that food supplies would be easily got, water was laid on, and building materials were ready to hand. The house was built on a terrace which had been levelled on the hillside, and I decided to set up the huts and instruments within a few feet of the verandah.

I am very much indebted to Mr. van Lessen for his kind assistance in numberless ways. Not only did he make me free to use the resources of the mines and the coolies employed there, for the purpose of setting up the huts and building piers for the instruments, but he and Mrs. van Lessen helped us in setting up house in rather unusual circumstances, by lending us furniture and in enlisting a similar kindness from the resident "Comptrolleur," Mr. Sieburgh. It is a pleasure to recall the readiness and interest with which the officers of the mines, under Mr. van Lessen's direction, helped us in our needs.

§ 2. *Position of Station.*

The station for the observations was at Ayer Karoe, at the N.W. end of the terrace, on which are built five houses for the overseers of the Oembilien mines. The site is a few hundred yards from the village Doerian, along the road leading from Sawah Loento to Talawi. The position, read off the Survey Map (scale 1 : 20,000), is longitude 0° 23′ 30″ E. of Padang, and latitude 0° 39′ 55″ S. Major Muller gave the Padang meridian as 100° 21′ 55″ E. of Greenwich.

The position of the station may accordingly be taken as—

Longitude ..... 100° 45′ 25″ E. of Greenwich.
Latitude ..... 0° 39′ 55″ S.
Height above mean sea-level at Padang, 1260 feet.

The spot is about 37 miles from the central line and on the north side of it. The duration of totality predicted from the elements adopted by the 'Nautical Almanac' was $5^m\ 42^s$, instead of $6^m\ 29^s$ on the central line.

§ 3. *Time Observations.*

From the top of a small hillock within two minutes' walk of the instruments we could see the camp of the Boston expedition near Sawah Loento, at a distance of 2·7 miles (measured on the Survey maps 1 : 20,000). Professors Burton and Hosmer were so kind as to make an arrangement by which we received time signals and so determined the errors and rates of the chronometer and watch which I had brought with me. Professor Hosmer had a white time-ball fixed that could easily be seen against the dark background of the tropical foliage with the help of binoculars; and it was arranged that on any day that we hung out a signal (three white flags) in the early morning, he would if possible drop the time-ball at $11^h\ 5^m\ 0^s$, again at $11^h\ 6^m\ 0^s$ and at $11^h\ 7^m\ 0^s$. His time observations for determining the errors and rates of his own chronometers were made with a 2½-inch portable transit and chronograph. Mr. Hosmer gave me signals on four days between the 9th and 19th of May. My watch—an excellent one by Frodsham, made for the 1862 Exhibition—was kept in exceptionally favourable conditions for good time-keeping, and its rate deduced from signals received on May 9 and 16 was + 4·6 seconds per diem, and from May 16 and 19 was + 4·6 seconds per diem.

The rate of the chronometer (by Crisp) was found to have changed from + $0^s\cdot7$ between the 17th and 18th to + $2^s\cdot1$ between 18th and 19th, the chronometer having been moved in and out of the hut several times for the preparatory rehearsals.

The following are the times of contacts observed, those predicted from the elements given in the 'Nautical Almanac' being given for comparison and position-angles of the contacts being also added for convenience of record :—

	Position angle.	Prediction, G.M.T.	Observed.
	°	hr. min. sec.	hr. min. sec.
First contact ..	253	16 5 15	16 5 31
Second ,, ..	48	17 39 12	17 39 17
Third ,, ..	288	17 44 54	17 44 52
Fourth ,, ..	82	19 17 20	Not observed

First contact was observed by me through the declination theodolite, the time of my call "Now" (possibly 5 seconds late) being noted on the Crisp chronometer by Lieutenant Briggs. Second and third contacts are those for Dr. Wallace's signal "Go" at beginning of totality when he was observing the disappearing current on the focussing plate of the Dallmeyer telephotographic camera (image of sun 1·43 inches in diameter) and for my signal "Now" given to Lieutenant

Briggs and Mrs. Newall for the exposures they had to make with their respective instruments for the reappearing flash.

These two observations were recorded in terms of the metronome beats, and were connected with the chronometer readings by my noting on the chronometer the instant at which the last call of the count with the metronome was made by the time-keeper.

The metronome was adjusted to beat seconds the night before the eclipse, and as set it lost one beat in 6 minutes. It was tested about a quarter of an hour before the eclipse, and again after the eclipse, and was found in several trials to lose between one and two beats in 6 minutes.

The photographs of the disappearing and reappearing crescents afford a check on these signals called both by Dr. Wallace and myself, but the discussion is not yet completed.

§ 4. *Meteorological Conditions.*

The following summary may be given of the records kept between April 24 and May 22 :—

Becloudedness.—Out of 23 days on which record was kept of the becloudedness of the sky near the zenith between 12 and 1 o'clock midday—the eclipse occurred at 12.22 P.M.—

1 was absolutely free from cloud and haze (May 1).
4 were free from cloud, but more or less hazy.
8 were completely overcast.
10 were more or less cloudy (including the day of the eclipse).

Temperature and Moisture.—The temperature was recorded for wet- and dry-bulb thermometers in the verandah :—

Time of day.....	6 A.M.		Midday.		Evening (about 9 P.M.).	
Number of days on which readings were recorded	19		11		7	
Thermometer.....	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.
Average	72°	71°	84°	78°	76°	74°
Highest.....	76	74	86	80	77	75
Lowest	69	67	80	74	75	72

Rain.—Records on 21 days :—

On only 2 out of 21 days, on which record was kept, was there rain between 6 A.M. and midday.

On 8 days there was no rain.

On 13 days there was rain in the afternoon or night.

Largest rainfalls recorded were:—

May 8	.....	1·19 inches	in 40 minutes.
„ 22	.....	1·72 „	2 hours.

§ 5. *General Programme of the Observations.*

The operations during the eclipse were to include—

1. Taking a series of photographs of the corona with the Dallmeyer telephotographic combination, in continuation of the series obtained in many recent eclipses, under the direction of the Joint Permanent Eclipse Committee.
2. Taking a series of photographs of the corona with the Savart camera, used at Algiers in 1900, for a study of the polarisation of the corona.
3. Taking a series of photographs of polarised images of the coronal with the double-image camera, devised and used by Professor H. H. Turner in recent eclipses.

   Nos. 1, 2, and 3 were to be done with the "double-tube" camera, which had been used in many eclipses. Professor Turner had very kindly lent me the apparatus for No. 3, but I had most reluctantly to give up the attempt to adjust it; the weather in the week before the eclipse was unpropitious, and I had to concentrate effort on completing adjustment of instruments already set up.
4. Taking a series of photographs of the spectrum of the chromosphere and "flash" at the beginning and end of totality, with a 4-prism spectroscope with slit, for accurate determination of wave-lengths.
5. Taking a photograph of the spectrum of the corona with the 4-prism spectroscope, two slits being used, to get material for the determination of the relative motion of the eastern and western parts of the corona (rotation of the corona).
6. Taking photographs of the "flash" and corona, with a powerful objective-grating camera, using very high dispersion.
7. Making visual observations of the structure of the green coronal ring, as viewed through another objective grating camera.
8. Taking photographs of the spectrum of the flash and corona with a quartz spectrograph giving small dispersion.
9. Making visual observations of the atmospheric polarisation with a view to detecting a change in the plane of polarisation during totality, and for the purpose of getting the information necessary for adjusting the Savart camera used in No. 2 during the eclipse.

§ 6. *Assistance.*

Throughout the preparations for the observations I received most valuable assistance from my friend Dr. L. Wallace, who travelled from Burma to Sumatra especially to help in the work of the expedition. Arriving at Sawah Loento on April 18, he accompanied us to Ayer Karoe, and assisted in every possible way to further the aims of the expedition from the moment of his arrival until all the instruments were packed up again on May 26 after the eclipse. It is a great pleasure to acknowledge my deep indebtedness to him for his friendly and efficient help.

A few days before the eclipse, Lieutenant-Commander Oldham, of H.M.S. "Pigmy," was good enough to tell off Lieutenant H. D. Briggs to come up to Ayer Karoe, together with two petty officers from the "Pigmy," to help in the final preparations, and in the observations. They took part in the preparatory drills and rehearsals, and gave most efficient assistance.

In the observations during the eclipse itself—

Dr. Wallace was in charge of the double tube camera, and gave the signals, watching the diminishing crescent of the sun upon the blue focussing plate of the Dallmeyer telephotographic camera.

Lieutenant H. D. Briggs exposed the plates for the objective-grating camera, after having assisted me in making the final adjustment with the diminishing crescent.

Mrs. Newall made exposures with the quartz spectrograph.

I made exposures with the 4-prism spectrograph, made observations for detecting the polarisation of the atmosphere, and observed the green coronal ring with the visual objective-grating spectroscope.

E. Hobart, Chief Stoker, and H. Taylor, Petty Officer, H.M.S. "Pigmy," counted seconds aloud from a metronome, and handed plateholders.

At 30 seconds before totality Dr. Wallace, watching the diminishing crescent of the sun, and gauging its length by a marked template which I supplied him with, gave a signal to Lieutenant Briggs, and at 15 seconds he called out "Stand by." Hobart began counting seconds with the metronome, until Dr. Wallace gave the signal "Go," when the disappearance of the crescent showed that totality had begun. Then Hobart ceased counting, and Taylor began afresh, and counted steadily on to the end of the third minute; in this count he began each minute with "one," "two," "three," and Hobart called "One minute gone," "Two minutes gone," at each new minute. Then Hobart resumed the counting of seconds, Taylor calling the minutes up to the completion of the sixth minute, it being expected that totality would last for $5^m\ 42^s$, if the prediction based on the 'Nautical Almanac' elements were true, or for $5^m\ 32^s$ if the prediction based on a recent

discussion of eclipse observations were true, Dr. Downing, the Superintendent of the 'Nautical Almanac,' having been good enough to write out to us in Sumatra about this result of the discussion. It was arranged that Hobart should continue the counting of seconds after totality was finished, so that I might note on the chronometer the instant at which the final "sixty" was called.

The operations were rehearsed several times on the two days before the eclipse, and everything went off as perfectly as rehearsals could make it. In a later paragraph reference will be made to one unforeseen mishap which arose from the interference of the clouds.

§ 7. *The Day of the Eclipse.*

When the sun rose and the morning mists were dispelled on the 18th—the day of the eclipse—the conditions seemed vastly more favourable than on any day in the previous week, during which it must be confessed we had rather a trying time, inasmuch as sunshine was needed for the final adjustment of the two spectroscopes, and it was very difficult to find moments between clouds when enough could be got.

The early hours of the morning of the 18th were occupied in completing the adjustments, which, as it turned out, were already nearly perfect, except in the case of the quartz spectrograph, as will appear in a later paragraph. The clocks for driving the cœlostat and the large spectrograph were finally rated, and we had gathered for a last rehearsal, more for the sake of establishing confidence than of adding to the instruction and drill, which had been gone through many times on the two previous days. But about 11 o'clock, very soon after I had observed the first contact, clouds began to move up from the N.E., and to form round the sun, and it began to be an anxious time. I was content to dispense with the rehearsal in dumb-show, and thus avoided the risk of inadvertent exposure of the photographic plates in the dark slides, preferring to give some finishing touches to the arrangements for signals, exposures, and observations. Nothing was lost by this procedure, and in the actual event the programme was perfectly carried out by everyone concerned, except that cloud interfered in an unforeseen way (see § 11, p 221) with my operations with the 4-prism spectrograph, thus curtailing my most important exposure by $2\frac{1}{4}$ minutes, and also involving the loss of one of the exposures with the double tube.

Fifteen minutes before totality the cloud was still hanging about, and obviously forming in some places and dispersing in others. Iris-coloured rings were seen round the diminishing crescent, showing that the clouds were water-clouds, not ice-cirrus. Ten minutes before totality I looked into one of the spectrographic instruments (see

§ 16, p. 231) and failed to distinguish in the dispersed image the light contrast between crescent and cloud. Five minutes later I exposed a plate in the 4-prism spectrograph, using the light reflected from the clouds near the sun; the resulting negative has unexpectedly great density. Four minutes before totality I was able, through a gap in the cloud, to adjust the visual objective grating (see § 17, p. 233), and 2 minutes later to perform a similar adjustment for the photographic objective grating, an operation which 8 minutes earlier I had given up as hopeless. The cloud was a sort of mackerel cirro-cumulus, giving momentary clear views of the crescent, which was more generally partially obscured by the flocculent masses. As the sunlight faded with the waning of the crescent, the visibility of this veil of cloud decreased, but its presence was clearly indicated by the coloured rings.

Cloud continued in greater or less degree throughout the whole of totality, as will be gathered from the record, given in the following paragraphs, of the observations made with the various instruments.

§ 8. *Huts for the Instrument and Dark Room.*

Two huts—wooden framework and Willesden canvas—were taken out to Sumatra.

One was 15 feet 2 inches long, 10 feet 10 inches wide (the length of the sides being multiples of 2 feet 2 inches, the width of the canvas), 6 feet high at the eaves, 8 feet 6 inches high at the ridge. The ridge-pole was not central, but 4 feet 2 inches from one side and 6 feet 6 inches from the other; two canvas-covered doors were provided, one in each long side, at the ends of a diagonal, and the framework of the hut was covered over with Willesden canvas, except over about two-thirds of one side of the roof. To cover this part six thin sheets of the lightest galvanised iron (6 feet by 2 feet, 10 lbs. to a sheet) were used as a roof which could be easily taken off when it was desired to make observations or to let in light and air into the hut, and which, when replaced, formed a water-tight roof that resisted even tropical rain. Over the hut, and quite separate from it, a light bamboo framework was erected by native workmen, and a thatching of rough grass ("alang-alang") was fitted over it, leaving only a space of a foot and a-half between it and the canvas roofing; the thatching was, of course, omitted over the galvanised-iron sheets. This hut was used to cover all the instrument, and was found extremely convenient.

The other hut was 10 feet 10 inches long, 8 feet 8 inches wide, 6 feet high at the eaves, 8 feet 6 inches high at the ridge. It had been used in Algiers for the instrument hut; on the present occasion it was converted into a photographic dark room. For this purpose a roll of Willesden waterproof paper, 5 feet wide, ordinarily used for under-slating, had been taken out to Sumatra, and was used to make the

canvas hut light-tight. The canvas was put on outside the framework, and the roof was thatched with "alang-alang" on the top of the canvas, to help to keep out rain and sun, and the thick paper was tacked in position inside the framework. This was done in such cunning fashion under Dr. Wallace's direction, that the hut was well ventilated, and I doubt if so convenient and comfortable a dark room has ever been constructed in the tropics.

With reference to the dark room, I may add that a good supply of ice for keeping the chemical and washing baths cool was obtained from Padang, but this was only used for the plates that had to be preserved. A great many of those taken in the process of adjusting the instruments were entirely rotted when ice was not used, but as these were only of passing value there was no object in preserving them.

§ 9. *General Arrangement of the Instruments.*

Inside the large hut three piers were built :—

(i.) One to carry the 4-prism spectroscope and the visual objective grating; top level and oriented north and south.

(ii.) Another immediately to the west of it to carry the cœlostat; top level and oriented north and south.

(iii.) A third, still more to the west, to carry the double tube camera, the photographic objective-grating camera and other apparatus, all inclined and pointing downwards towards the cœlostat; top inclined at an angle 22° with the horizon, and in azimuth 70° west of south.

The hut was set so that one diagonal of the base was parallel to the length of the third pier, or in other words, to the double tube camera; the long sides of the hut thus lay nearly east and west. The part of the roof over the N.E. corner was covered with the movable corrugated iron, so as to admit the sunlight to the cœlostat and 4-prism spectroscope below.

The two clocks for driving the cœlostat and the 4-prism spectroscope were put on piers just outside the north side of the hut, and were protected by sheets of corrugated iron leaning against that wall of the hut. The weights for the cœlostat clock were hung over a pulley attached to the bamboo framework that supported the thatch.

The visual polariscopes were fitted to the framework of the hut up in the N.E. corner.

§ 10. *The Cœlostat.*

The 16-inch cœlostat, which was used by Professor Turner in India in 1898, and in Algiers in 1900, had been specially provided, by the care of Dr. Common, with an additional support to the mounting, which made it quite stable and suitable for use on the equator. The

mirror, made by Dr. Common and silvered by the Improved Electric Glow-Lamp Company, had a very fine surface, which was found in admirable condition when it was unpacked and put into its mounting on May 14. All the preliminary adjustments of the polar axis of the instrument had been made by means of the attached declination-theodolite, as in recent eclipses. Dr. Common kindly lent me a 6-inch flat, silver-on-glass mirror (also silvered by the above-named Company), and I used it once or twice before May 14, temporarily fitted to the mounting of the cœlostat; for it seemed safer in the tropical climate to run as little risk as possible with the 16-inch mirror, though I had, thanks to the kindness of Mr. Hinks, taken out silvering solutions in case of need. The final adjustment of the polar axis of the instrument was completed after the large mirror had been put in position in the mounting, and calls for no special mention.

The tilt of the mirror—*i.e.*, the perpendicularity of its normal to the polar axis—was tested by making the polar axis horizontal, as judged by the readings of the level on the theodolite, and then comparing the readings of a small level carefully placed on a sheet of paper on the silvered surface of the mirror, with the readings of the theodolite level. This procedure was regarded as sufficient and satisfactory for a place close to the equator, though exception might be taken to it were it adopted in higher latitudes.

§ 11. *The 4-prism Spectroscope with two Slits.*

It was intended to attempt—

(i.) To secure five photographs of the bright-line spectrum of the sun's limb at the beginning of totality, and six others at the end, one slit only being used.

(ii.) To photograph the spectrum of the corona in both eastern and western equatorial regions to get material for determination of the relative motion in the line of sight (rotation of the corona), two slits being used.

The instrument arranged for this work is a 4-prism spectroscope with two slits. It was used by the writer in India at Pulgaon in 1898,* and at Algiers in 1900.†

The train of prisms is of such dimensions and construction as to transmit a 2-inch beam of light and to produce a minimum deviation of 180° for H_γ. The camera and collimator are set parallel to one another.

The whole spectroscope is mounted so as to turn about an axis

* 'Roy. Soc. Proc.,' vol. 64, p. 55; 'Monthly Notices, Roy. Astro. Soc.,' vol. 58, App. p. [55].

† 'Roy. Soc. Proc.,' vol, 67, p. 356; 'Monthly Notices, Roy. Astro. Soc.,' vol. 60, App., p. [20].

parallel to the collimator. The axis is rotated (with a period of 24 hours) by clockwork, and is tilted so as to be parallel to the earth's axis. It was adjusted so that the collimator pointed to the south pole and the camera to the north pole.

The tube of the collimator is prolonged beyond the plane of the slit, and is arranged to carry at its end a mirror of speculum metal and an object-glass, by means of which an image of the sun can be thrown between the two slits.

The whole arrangement thus consists of a spectroscope combined with a polar heliostat, and in virtue of the fact that the spectroscope is rotated together with the mirror, the image of any celestial object thrown on the slit does not rotate relatively to the slit. The mirror is mounted in such a manner that the axis about which it is tilted can be oriented relatively to the collimator tube, so that the slits may be set parallel to any diameter of the sun. On the present occasion the slits were set parallel to the axis of the sun.

In India the slits were set at too great a distance apart, and the light of the corona was not strong enough to impress the photographic plate; the slits were set so as to catch the corona nearly 8′ from the sun's limb on each side. In Algiers the instrument was used with only one slit, and the spectrum of the corona was photographed in two regions to a distance $3\frac{1}{4}'$ from the limb with an exposure of 49 seconds, and the resulting negative was a good strong one. In Sumatra I expected to be able to get an exposure of 270 or even 300 seconds, and to avoid risk of disappointment the slits were set at such a distance apart as to catch the corona 3′ from the sun's limb on each side. This distance was as small as it seemed wise to adopt, account being taken of the apparent diameter and movement of the moon during totality.

The instrument was fairly well adjusted on May 2, and I then took the opportunity afforded by a clear night to throw an image of the full moon on to the slits. It was brightly seen and easily adjusted; but to make matters more certain, I painted the slit-plate white, so that there might be no possible difficulty in setting the image of the corona between the slits after the exposures had been made for the "flash" spectrum with the crescent across one of the slits. The sequel will show that even this precaution was not enough under the circumstances.

The adjustment of the axis of the instrument to parallelism with the earth's axis was accomplished in the same way as in India and Algiers by means of a theodolite with declination circle and level, which was attached to a part of the frame of the spectroscope specially prepared for it.

The rotating plate-holder, charged with twelve small plates, was again used for the exposures as in Algiers.

I was observing the diminishing crescent through the guiding eye-piece of the spectroscope when Dr. Wallace called out "Stand by," and at once hastened to the plate-holder to make exposures for the "flash." Five exposures had been made, each twice as long as I had intended to make had there been no cloud, and as the counting went on longer than. I anticipated I decided to make one more exposure, thus using a sixth plate at the beginning of totality. Immediately after having moved Plate No. 7 into its place with shutter closed, I returned to the guiding eye-piece to set the corona ring between the slits. I could see one side of the faint ring distinctly, but could not see the slits, but having learnt by experiment in the course of the morning what movements of the declination and R.A. slow-motions were required to move the image from one position to the other, I made those movements and, being still unable to see the slits, looked up at the corona. There was no difficulty in seeing the dark moon, so to speak, but the corona was quite indistinct beneath the cloud, and was surrounded by a colourless bright ring, which is referred to in the "General Remarks." My notes, written directly after the eclipse, contain the following:—

"I heard count 'Thirty,' and took a candle lamp [which was standing in the tent] to try to illuminate the slit-plate, but failed to get light in. Then, as 'Thirty-five' was called, I turned to polariscope. No trace of polarisation. Turned to second polariscope and could see no trace of polarisation, but saw mackerel sky very strong as it seemed, all over region near the sun, especially to N.E. . . . Returning to 4-prism spectroscope I found the whole ring of the corona visible, but still could not see the slits. Tried candle again; no use. 'Two minutes gone' was called. Ring was clearly lighter, but slit not visible; cloud pretty strong over corona, which could only be traced about half a diameter from the limb. I walked towards double tube and met W. [coming back into hut], who was I thought waiting for improvement in cloud. He asked, 'Is Savart set.' . . . [I replied 'Yes' and] he at once exposed plate-holder No. 2 in the double camera, and I heard '2^m 35^s' called as I walked back to spectroscope. Corona was brighter, and I found slits visible, and moved corona ring on to the right place and exposed at 2^m 45^s [having lost two minutes and fifteen seconds, exactly half the intended exposure]. Then I turned to polariscope and still failed to see any bands, and then went to visual grating . . . Clouds seemed thinner when I looked up at sky, and Mercury and Venus were very bright. I had one more look at corona on the slits of 4-prism [and found it still correctly adjusted on the slits, and the clockwork evidently driving well], and then as Briggs came back into hut, I looked at polariscope for third time and again failed to see any bands on sky. At 5^m 0^s I saw B. and Mrs. N. close their exposures, and I closed mine at 5^m 3^s, the rubber band of

shutter sticking rather. Then re-set bright side of corona according to picture [previously made to indicate position angle of crescent on slit], and began to expose the five remaining plates in 4-prism [for second 'flash']. At $5^m\ 35^s$ I called 'Now' to Briggs and Mrs. N. for their final photographs, when I felt end of totality had come . . . [I turned to chronometer and waited for] W.'s signal 'Now,' which was to mean the 15-seconds crescent [of returning sun]. I noted this on chronometer, and waited further for Hobart's final 'Sixty,' which I also noted on the chronometer. Called 'Cover slides,' and then went out of hut and saw mackerel cloud all over the sky near the sun and 'glory' rings coloured round crescent. Sky got rapidly more clouded, and clouds drifted slowly towards west. Collected notes from observers."

Summary of Exposures.—Six exposures were made near second contact with the following durations :—

1 second, 1 second, 2 seconds, 2 seconds, 2 seconds, 3 seconds.

The seventh plate was exposed for the corona spectrum for $2^m\ 18^s$. Five exposures were made near third contact with the following durations :—

2 seconds, 2 seconds, 1 second, 1 second, 1 second.

Results.—Of the twelve plates thus exposed, only four plates show any impress of the light. The rest, including the exposure on the corona, show nothing, though development was pressed as far as possible.

Five minutes before totality a photographic plate was exposed for 15 seconds to get the spectrum of the sunlight reflected from the clouds near the crescent—this was to serve to give standard measurements to which the measures of the corona spectrum were to be referred—and a good strong negative was obtained.

The plates at second contact are very feeble negatives, and I attribute their weakness to cloud. Photographs obtained with the other instruments at the beginning of totality show that at least three-quarters of the light was intercepted by cloud.

The spectrum of the corona failed because of insufficient exposure under the cloudy conditions.

The plates at the end of totality, when there was certainly very much less cloud, show no sign of impress of the light, and I can only explain it by assuming that the image of the reappearing crescent must have been set across the slit in such a way that three or four more exposures than I had the means of giving were needed to catch the reappearing chromosphere. Photographs obtained with the objective grating show that there was plenty of light to impress the plate, if only it had passed into the slit.

§ 12. *Dallmeyer Telephotographic Camera.*

The double camera used by Professor Turner at Sahdol in 1898 and at Algiers in 1900 was used on the present occasion in the modified form adopted at Algiers. One of the 7 × 7-inch tubes contained the photoheliograph objective No. 2, of 4-inch aperture and 5-feet focal length, with a Dallmeyer secondary magnifier of 7½ inches focus, placed 5 inches within the focus, giving an image of the sun 1·43 inches in diameter on plates 6¼ × 6¼ inches.

The method adopted for focussing was first to focus on trees on a distant hill top, viewed through blue glass, and then to use the collimating process, adopted in many recent eclipses. A plane mirror set perpendicular to the axis of the camera reflects rays emerging from the objective back again through the objective; the image of objects in the focal plane is thus formed in the focal plane. The mirror used on the present occasion was the 6-inch kindly lent to me by Dr. Common, and a negative, specially prepared with an image of a finely graduated scale in white on a black ground, was used as the object to be focussed on a sensitive plate, which was put in the same plane with it. Four trials gave sufficient data to set the focus accurately.

The results obtained in the eclipse are as satisfactory as the lenses will give, and it seems right to suggest that some other lenses be used, if it is decided to take this kind of photograph of the corona in future eclipses.

The programme of exposures with this camera was of necessity the same as that adopted for the polariscopic images referred to in § 13, p. 227, for the exposures were made by means of the one shutter for both cameras. The six slides were filled with Ilford Empress plates, and all six were to be exposed during totality if circumstances allowed. It was intended, if the sky was clear, that the exposures should include the series, 2ˢ, 4ˢ, 8ˢ, 16ˢ, 32ˢ, and another long one (120ˢ) with diminished aperture; and in case of cloud the long exposure was, if necessary, to be sacrificed altogether, and the exposures in geometrical series were to be secured, if possible, in clear intervals. The order of the exposures was to be:—

1. 8 seconds, followed by an interval in which the Savart camera would be set by me after visual observations of the atmospheric polarisation had been made.
2. 16 seconds.
3. 32 seconds, after which Dr. Wallace was to put a cap on the lens to diminish its aperture.
4. Long exposure, to be sacrificed if necessary; after this the cap was to be removed again from the lens.
5. 4 seconds.
6. 2 seconds.

In the event, the long exposure was sacrificed, the other five were made.

The actual exposures were :—

1. 8 seconds, beginning 10 seconds after the signal "Go."
2. 17 „ „ 2 minutes 35 seconds after the signal "Go."
3. 36 „ „ 3 „ 15 „ (? ± 5 seconds).
4. Omitted.
5. 4 seconds, beginning 5 minutes 3 seconds after the signal "Go."
6. 2 „ „ 5 „ 18 „ „ „

The first exposure was made through clouds.

The interval between the first and second exposures was more than 2 minutes longer than it would have been had the sky been clear. In the third exposure one of the shutters had evidently not acted, the photograph showing nothing but the standard squares, which had been put on just before development. The last two exposures were carried out according to programme, and were made probably at moments when the sky was clearer than at any other time during the whole eclipse.

The Standard Squares.—After the eclipse, Sir. W. Abney's standard squares were impressed on all the plates for photometric measurements. Exposures were made to a standard candle at 5 feet from the plate, and, following a suggestion made by Professor Turner after his experience with the plates taken at Algiers in 1900, two sets of squares were impressed, with different exposures, on all the plates, as follows :—

Plate.	Exposure for corona.	Exposure for standard squares.
No. 1	8 seconds	10 seconds and 5 seconds
„ 2	17 „	20 „ 5 „
„ 3	36 „	80 „ 5 „
„ 4	not exposed	80 „ 5 „
„ 5	4 seconds	80 „ 5 „
„ 6	2 „	20 „ 5 „

Development.—All the plates were developed with metol.

When it was found that there was no image on No. 3—one of the exposing shutters evidently had not acted—it was thought wise to impress squares on No. 4, and develop it, just for the very improbable chance that it had been exposed in mistake for No. 3, but no image appeared on the plate.

Results.—The four photographs obtained are all good clean plates. The effect of the cloud is clearly seen in the plates, though it is surprising that the definition has not been more affected by it. The first exposure (8 seconds) shows less than the last (2 seconds);

and the second (17 seconds) shows very little more than the fifth (4 seconds).

The form of the corona is clearly of the type associated with the minimum in the sunspot cycle.

The eastern equatorial region shows great disturbance, and there are many striking prominences on the eastern limb and several marked arches. In particular, reference may be made to (i) two dark rifts radiating from the neighbourhood of a prominence near the sun's equator, on the east side; (ii) bright and dark arches in no less than three of the quadrants, extending about 4′ from the limb; (iii) a dark region surrounding a large prominence whose position-angle is approximately 20° measured from the N. point of the sun; and (iv) a remarkably definite edge as of a chromospheric layer for a considerable arc of the sun's limb, in the N.W. quadrant, such as Sir Norman Lockyer described as seen in the photographs secured in Spain last year.

A summary is given below of the extension noted in the different photographs—extension being measured beyond the *moon's* limb, and expressed in minutes of arc :—

	Plate No. 1. 8 seconds.	No. 2. 17 seconds.	No. 5. 4 seconds.	No. 6. 2 seconds.
North polar streamers	5′	15′	21′	5′
East equatorial	8	23	19	8
West „	5	22	12	9
South polar	3	10	8	4

§ 13. *The Polariscopic Camera (Savart Plates and Nicol Prism).*

The Savart camera, which was constructed for use in Algiers, was to be used on the present occasion with a view to getting information as to the amount of polarisation in the outer regions of the corona, and, in particular, in the search for the position of maximum polarisation.

Professor J. J. Thomson very kindly put the large Nicol prisms from the Cavendish Laboratory collection at my disposal again, and the Savart plates were arranged in the same way as last year.*

The camera was put in the second compartment of the double tube, side by side with another camera which was provided with a similar lens, but had no polarising apparatus in front. In this way images of the same scale were obtained side by side on the one plate, one image being taken through the polariscopic camera, the other through the plain camera, each camera having an aperture approximately F/27.

* 'Proc. Roy. Soc.,' vol. 67, p. 363; 'Monthly Notices, Roy. Astro. Soc.,' vol. 60, App., p [27].

The cameras were focussed on trees on a distant hill viewed through blue glass, and gave satisfactory images.

The programme of exposures was the same as that for the Dallmeyer telephotographic camera, as follows :—

8 seconds, 16 seconds, 32 seconds, 120 seconds, 4 seconds, 2 seconds,

thus including one long exposure, and five others in geometrical progression, it being intended to compare the polarised image on one plate with the unpolarised image on the plate next before it in the series. The Savart was to be set in accordance with the result of visual observations of the atmospheric polarisation, so that the bands due to atmospheric polarisation should be obliterated. The first photograph was made with an arbitrary setting of the Savart, and the setting chosen was one that would give the coronal bands slightly inclined to the sun's equator. In the event no atmospheric polarisation was detected, and the Savart was left at the same setting throughout all the exposures. Mr. Wallace made simultaneous exposures for these and for the Dallmeyer telephotographic camera.

Results.—As in the case of the Dallmeyer telephotographic camera, four photographs were obtained, standard squares being impressed on each plate after the eclipse with a standard candle at 5 feet.

	Exposure for corona.	Exposure for standard squares.
No. 1	8 seconds	10 seconds and 5 seconds
,, 2	17 ,,	20 ,, 5 ,,
,, 5	4 ,,	20 ,, 5 ,,
,, 6	2 ,,	— ,, 5 (one only).

All the photographs with the Savart camera are good clean plates and show marked polarisation of the corona. The following table summarises the extensions of the coronal streamers in the unpolarised images and of the bands in the polarised.

Extensions expressed in Minutes of Arc from Moon's Limb.
P = Polarised Image. U = Unpolarised.

Plate.....	No. 1.		No. 2.		No. 5.		No. 6.	
Exposure	8 seconds.		17 seconds.		4 seconds.		2 seconds.	
	U.	P.	U.	P.	U.	P.	U.	P.
North polar streamers	8′	?	20′	28′(?)	15′	10′(?)	8′	?
East equatorial	13	57′	46	69	29	28	15	10′
West ,, ...	8	49	41	97	29	34	20	23
South polar	5	?	16	?	11	?	8	?

In estimating extensions in the unpolarised images no account was taken of light, which it seemed fair to attribute to diffusion from clouds. Extension was gauged along *streamers*, not in structureless luminosity. In many cases bands can be traced in the polarised images further than streamers in the unpolarised.

Many years ago Sir G. G. Stokes pointed out that the Savart polariscope might be used for the detection of faint extensions of the corona, and it may be that these photographs give evidence of the value of that suggestion.

Across the dark moon very faint bands are detectable only in the 17-second exposure. I am not yet prepared to say how far the discussion of the results may lead me to attribute the extension of the bands to the diffusion of polarised light which emanates from the corona by terrestrial clouds, but it is clear that the resultant polarisation of such light must be, so far as the Savart bands are concerned, in a plane parallel to the equatorial extensions.

The value of the photographs, *as a series*, with related exposures is much interfered with by the variation in the effect produced by cloud, and in consequence it will hardly be possible to utilise them for finding at what distance from the sun there is the maximum relative polarisation, even were the impressed extensions great enough. But as each plate had two exposures made on it simultaneously, one of the polarised image and one of the unpolarised, it is anticipated that they will serve well for the determination of the amount of polarisation in many regions of the corona.

The accompanying figure (fig. 1) indicates the contours of equal brightness in the two images, polarised (dotted line) and unpolarised (unbroken line) obtained in the second (the longest) exposure. It is reduced from a drawing made on a screen on which the two images were successively thrown by means of a lantern. The most marked streamers in the corona are indicated as well as the contours. No great precision has been aimed at in the diagram, its object being merely to give an idea of the sort of material obtained for the investigation. The phenomena are somewhat complicated; in consequence of the radial polarisation of the corona, the bands in the quadrants through which the central band passes form a system with white centre, those in the other quadrants form a system with dark centre; the two systems meet along lines passing through the centre and inclined at 45° to the central band. Hence some care must be exercised in interpreting the appearances presented.

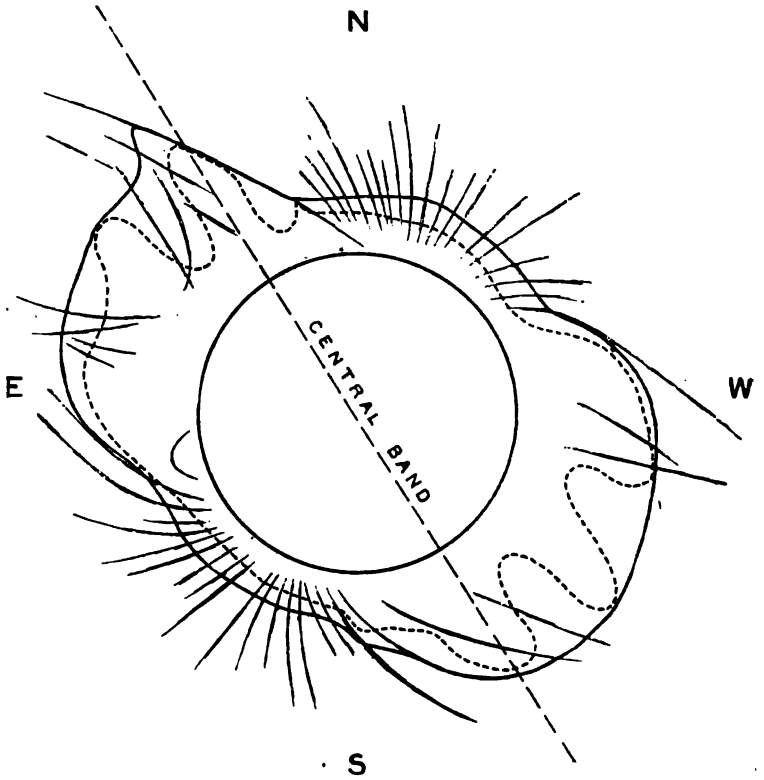
§ 14. *Atmospheric Polarisation.*

The Savart polariscopes A, B, and C were fixed on the framework of the hut in such position that the sky in the neighbourhood of the

eclipsed sun could be seen through them. Each was mounted in a turning tube, provided with a pointer and graduated circle and attached to a wooden stand.

The programme of observations was that I should look through A as soon after the beginning of totality as the adjustment and exposures of the 4-prism spectroscope would set me free. The polariscope was to be then turned in its tube until the Savart bands were invisible, and

FIG. 1.



I was at once to set the large photographic Savart camera to the corresponding reading, and to call out to Mr. Wallace, who was making the exposures for that camera.

Next the polariscope B was to be used half-way through totality, when my visual observations with the grating-spectroscope were completed. Finally the polariscope C was to be used towards the end of totality, just before the fifth minute was completed. Each of the polariscopes was to be left as adjusted "for extinction," and the readings were to be made at leisure after the eclipse, except in the case of A, of which the readings were needed at once.

Result.—In the event I used A about 40 seconds after the beginning of totality, and found no trace of polarisation in any position of the instrument. To make sure that nothing was wrong I used also polariscope B, and corroborated the first observation.

Towards the end of the third minute—$2^m\ 50^s$ from the beginning of totality—I again observed with B. At the end ofthe fifth minute I used C; and in neither case could I detect a trace of atmospheric polarisation. About 3.50 P.M., after the eclipse was over, I used the polariscopes again, and found them all as adjusted in the morning before the eclipse; each one showed showed strong bands on the patches of blue sky visible in the field of view.

§ 15. *The Quartz Spectrograph.*

It was intended to attempt to get—

(i) Photographs of the ultra-violet spectrum of the flash at the beginning and end of totality.

(ii) A photograph of the ultra-violet spectrum of the corona.

The instrument was fixed on the top of the double tube, and was supplied by light from the cœlostat. The arrangement was such that the slit could be set, without readjustment of the image, to catch the crescents both at beginning and end of totality, and the corona during totality. No other medium but quartz was used in the lenses and prisms, and the dimensions were such that a 2-inch beam was transmitted. The image lens had a focal length of 20 inches, and the collimator and camera lenses were each of focal length 18 inches; the prism was compounded of two 30° prisms, one of right-handed and the other of left-handed crystal; all the optical parts were constructed by Hilger. Unfortunately it was found impossible to get the adjustments completed before the eclipse.

On the morning of the eclipse a final attempt was made, and it was thought well to make the exposures according to programme. These were all duly made, but the adjustment was so imperfect that the photographs are useless, which is all the more regretable as the plates show strong spectra.

§ 16. *Photographic Objective-grating Camera.*

It was intended to attempt to get—

(i) Photographs of the "flash" spectrum with high dispersion in a limited range of spectrum, to assist in the discussion of the origin of lines, whose wave-lengths it was hoped would be determined accurately by means of the 4-prism spectroscope.

(ii) A photograph of the blue coronal ring near λ 4231, for comparison with the visual observations of the green coronal ring.

The instrument employed was in essentials that used at Algiers in 1900, but it was mounted differently.

A plane grating by Rowland, 14,438 lines to the inch on a ruled surface $5 \times 3\frac{1}{2}$ inches, was fitted on an axis in front of a telescope of aperture 4 inches and focal length 66·8 inches. The grating is a very brilliant one; the objective is an excellent one, corrected for photographic rays, by Cooke and Sons; and both belong to the splendid spectroscopic installation arranged by the late Professor Piazzi Smyth. I am under great obligation to the Royal Society for the continued loan of this outfit.

The telescope with grating attached was fixed inclined at an angle of 20° to the horizontal and pointing downwards on the sloping pier which supported the double camera, the telescope and camera being parallel. Part of the beam reflected by the cœlostat was allowed to fall on a 6-inch mirror, and thereby reflected downwards on to the grating. By inclining the plane of this reflection by the proper amount with the vertical, it was possible to get the crescent at second contact symmetrically disposed with respect to the plane of dispersion of the grating. It was thought best to run the risk involved in the loss of light for the sake of getting the telescope into the very convenient position of parallelism with the double camera, and on the same sloping pier with it.

The light reflected by the small mirror fell upon the grating with an incidence of 39°, and the diffracted beam left the grating at an angle of about 5° on the other side of the normal. In this position H_γ in the spectrum of the second order was not far from the centre of the field of view of the telescope.

The focussing and final adjustment of the spectrum on the focussing plate was intentionally left to be done a few minutes before totality, when the width of the diminishing crescent would make it possible to recognise the exact part of the spectrum in the field of view. Ten minutes before totality the cloud was so obscuring that on looking into the eye-piece I could not distinguish between the spectrum of the crescent and light reflected from the clouds. Returning to the instrument 6 minutes later I found the lines visible, and Lieutenant Briggs, who was to take charge of the exposures with this instrument, turned the tilting screw of the grating till I could see that the dark crescent-shaped lines near λ 4231 were in the centre of the field. I then focussed very carefully, and handed over the instrument to Lieutenant Briggs.

Programme.—Exposures were to be made—

(i) For 1 second when the signal "Stand by" was called by Dr. Wallace 15 seconds before totality.

(ii) For 2 seconds when the count "Thirteen" was called before totality.

(iii) For 4½ minutes, starting at the count "Thirty" after the beginning of totality and ending at the count "Sixty,—five minutes gone."

(iv) For 2 seconds, when I gave the signal "Now" at the end of totality.

Lieutenant Briggs carried out the programme with admirable precision.

Result.—All four photographs are of value. The first serves for determination of the scale of the spectrum and shows that the focussing was very successful. The second and fourth photographs show both bright and dark lines, as was intended; the second is a weak negative, but is full of interesting details; the fourth is quite strong, teeming with bright crescents, of which more than ninety have been counted between λ 4308 and λ 4405. Many of the crescents are bright throughout their whole length; many are reversed in the middle; some of the bright crescents are accompaned by dark crescents on either side; others have a dark crescent only on one side or the other; all varieties seem to be represented.

The third photograph is not very strong but it shows marked continuous spectrum, with the blue coronal ring distinctly though not easily visible. The edges are ill-defined, in marked contrast with the sharp prominence-tips that serve to mark out the positions of the H_γ and H_δ chromospheric rings.

The radial extension of the blue coronal ring is about 3′, but there is no sign of radial structure.

Two determinations of the wave-length of the light forming the blue ring give the values 4231·4 and 4231·9, if the wave-lengths ascribed to the dark H_γ and H_δ lines may be adopted for the bright hydrogen prominences.

The dispersion is about 5·14 tenth-metres to a millimetre, and the scale of the ring is such that its diameter corresponds to 65 tenth-metres. The conditions are thus favourable for the detection of coronal rings. No ring except that at 4231 has been with certainty detected between H_γ and H_δ.

§ 17. *Visual Objective-grating Spectroscope.*

An objective grating spectroscope was used as in India, in 1898,* for visual observations of the green coronal ring, with a view to (i) repeating the search made during the Indian eclipse for fine radial streamers, (ii) comparing the distribution of light in the green ring with that in the blue ring near λ 4231, of which I hoped to get a photograph with a photographic objective grating camera.

A plane grating by Rowland, 14,438 lines to the inch, on a ruled

* 'Roy. Soc. Proc.,' vol. 64, p. 57; 'Monthly Notices, Roy. Astro. Soc.,' vol. 58, App., p. [57].

surface $3\frac{1}{2} \times 2\frac{1}{8}$ inches, was fixed on a turn-table in front of a telescope of aperture $3\frac{1}{2}$ inches, and focal length 29 inches. A positive eye-piece with two cross-wires was used, which gave a magnifying power of 19·2, and whose circular field of view was rather more than 1° in diameter.

The instrument was mounted so that the telescope was parallel to the earth's axis and pointed to the south pole. The grating was used in a manner analogous to that in which the mirror of a polar heliostat is used. The light of the corona was incident at an angle of about 57°, and the diffracted beam utilised in the telescope left the grating at an angle of about 13°. In this position of the grating, the green of the second order was used and the magnifying power of the grating was approximately one-half, so that the distorted coronal ring was an ellipse, of which the major axis was about twice as long as the minor axis, the minor axis being parallel to the length of the spectrum and perpendicular to the direction of daily motion. No clockwork was used, but a wedge pushed under a wooden arm fixed to the instrument and projecting radially outwards from the telescope served to give a satisfactory slow motion by slightly turning the whole instrument about what may be described as polar pivots.

The instrument was focussed on the E group of lines about two minutes before totality began. The crescent was small enough to show the lines sharply, though the instrument was so set that the point of second contact was near the end of the major axis of the distorted image.

When I came to make observations of the green coronal ring, I first looked very carefully for fine radial structure; and finding none, I altered the focus very slightly. This did not improve matters, so I reverted to the original focussing, and am quite satisfied about the observation, which could not be more definite.

The observations were begun after the completion of the third minute of totality and were completed in about 80 seconds. Two ellipses had been drawn beforehand to serve as outline for the distorted limb of the moon; and on one of these the record of contour lines of the brightness was quickly but carefully sketched.

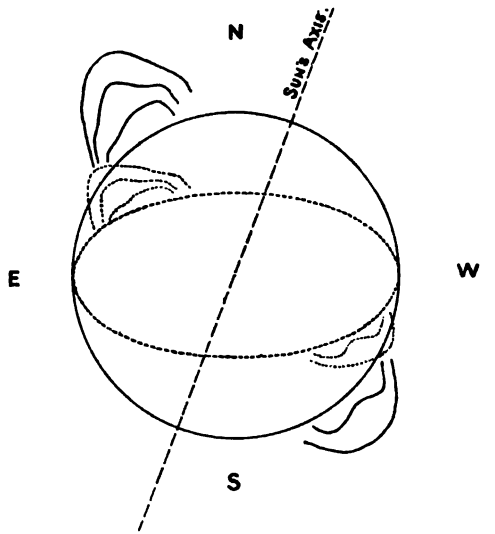
Results.—The coronal ring was distinctly seen, but there was a good deal of other green light throughout the whole of the field of view, doubtless from clouds. No fine radial structure could be seen anywhere round the ring; but there were two broad patches of the light of "coronium" projecting from the elliptical ring.

The accompanying figure (fig. 2) shows by the dotted lines the ellipse drawn beforehand, and the contour lines as sketched in during the eclipse. The unbroken lines indicate the results got by projecting the ellipse into a circle and making the corresponding change in the contour lines.

§ 18. *General Observations.*

The general darkness during totality was greater than that in India, 1898, and in Algiers in 1900, but not so much greater as was anticipated from the great length of duration of totality. No integrating photometer was used. Lamps and candles were provided in case of need, but they might have been dispensed with except for one adjustment.

FIG. 2.



The figure shows, by contour lines of equal brightness, the position of the two bright patches of incandescent "coronium" seen in the corona.

During totality I noted several times an uncoloured ring of light round the moon. It was evidently of terrestrial origin—in fact, a ring such as apart from an eclipse would be described as a "corona." The radius of the ring was estimated as about 1 or $1\frac{1}{2}°$. The equatorial streamers of the true solar corona were estimated as being visible not further than a quarter of a degree from the moon's limb, being then lost in general diffused light. The peculiar feature about the ring, as a phenomenon of diffraction due to the small particles of water forming the cloud to which it was without doubt due, was that the maximum of brightness appeared to be in the ring itself rather than near its centre. After totality colours again appeared in it, but I did not note nor can I recall the diameter of the rings.

"Total Eclipse of the Sun, 1901 May 18. Preliminary Account of the Observations made at Pulo Aoer Gadang, West Coast of Sumatra." By F. W. DYSON, M.A., F.R.S., Sec. R.A.S. Received October 24,—Read at Joint Meeting of the Royal and Royal Astronomical Societies, October 31, 1901.

I. *General Arrangements.*

The Admiralty having approved of expeditions from the Royal Observatory to observe the Solar Eclipse of 1901, May 18, I was instructed by the Astronomer Royal to occupy a station on the West Coast of Sumatra with the instruments used at Ovar in the eclipse of 1900, May 28. Mr. J. J. Atkinson, who accompanied the Observatory expedition to Ovar, again generously volunteered his assistance and is associated with me in all the observations. His advice and co-operation were of the greatest value throughout.

The programme of observations, which was arranged in concert with the Joint Permanent Eclipse Committee, was essentially the same as that carried out at Ovar.

The 16-inch cœlostat and the 4-inch rapid rectilinear (Abney) lens were lent by the Royal Astronomical Society, and Captain Hills kindly lent the spectrosopic equipment he used at the Indian eclipse, viz., a two prism flint spectroscope, a four prism quartz spectroscope, and a 12-inch heliostat.

At the request of the Royal Society the Admiralty placed H.M. gunboat "Pigmy" at the service of the observers in Sumatra. We are indebted to Lieut. and Com. Oldham for the ready manner in which he assented to our request to anchor off Gadang, and let us live on the "Pigmy." Without his cordial co-operation this station could not have been occupied. We are further indebted to him and to the officers and men of the "Pigmy" for assistance in erecting the huts and instruments, and for the large share they took in the observations on the day of the eclipse.

We received every assistance from the Government of the Dutch East Indies in the choice of station and arrangement with the natives, and were given free passes for ourselves and instruments on the railways. We are specially indebted to Mr. Joekes, the Governor of the West Coast of Sumatra, to Mr. Von Locken, the Assistant Resident at Painan, to Major Müller, the Director of the Ordnance Survey and Chief of the Dutch eclipse party, and to Mr. Delprât, the Director of Railways.

Itinerary.—The observing huts and instruments having been despatched some days previously, the 16-inch cœlostat mirror and some of the photographic plates were taken to Southampton and put

on board the Dutch mail steamer "Koningen Regentes," at Southampton, on March 4. The observers joined the ship at Genoa, on March 14, and sailed in company with Mr. and Mrs. Newall, the Dutch eclipse party, and an American eclipse party from the Massachusetts Institute of Technology, direct to Padang in Sumatra, arriving there on April 6.

In consultation with Mr. Joekes the Governor of the West Coast and Major Müller the Director of the Ordnance Survey as to choice of station, it appeared that the small island of Pulo Aoer Gadang might be suitable, and the Governor kindly offered us the use of his yacht to visit the island on March 10. In company with Mr. Von Locken we chose a suitable site and made the necessary arrangements with the native chief who owned the island. Lieut. and Com. Oldham conveyed us with our instruments and materials for building huts to Gadang on March 13, and remained anchored off Gadang, except for short necessary visits to Padang for ice, fresh meat, &c., till May 25, one week after the eclipse. On this day the instruments were brought back to Padang for shipment to Europe, and the observers were conveyed to Singapore, which was reached in the early morning of June 2.

Station.—The particularly uncertain character of the weather in Sumatra made it desirable that stations as far apart as possible should be occupied by the different parties of observers. The stations occupied by different expeditions are shown on the accompanying map (A).

Sawah Loento, by Mr. Newall and by a party from the Massachusetts Institute of Technology.

Solok, by numerous American observers of the United States Naval Observatory expedition.

Fort de Koch, by American and Dutch observers.

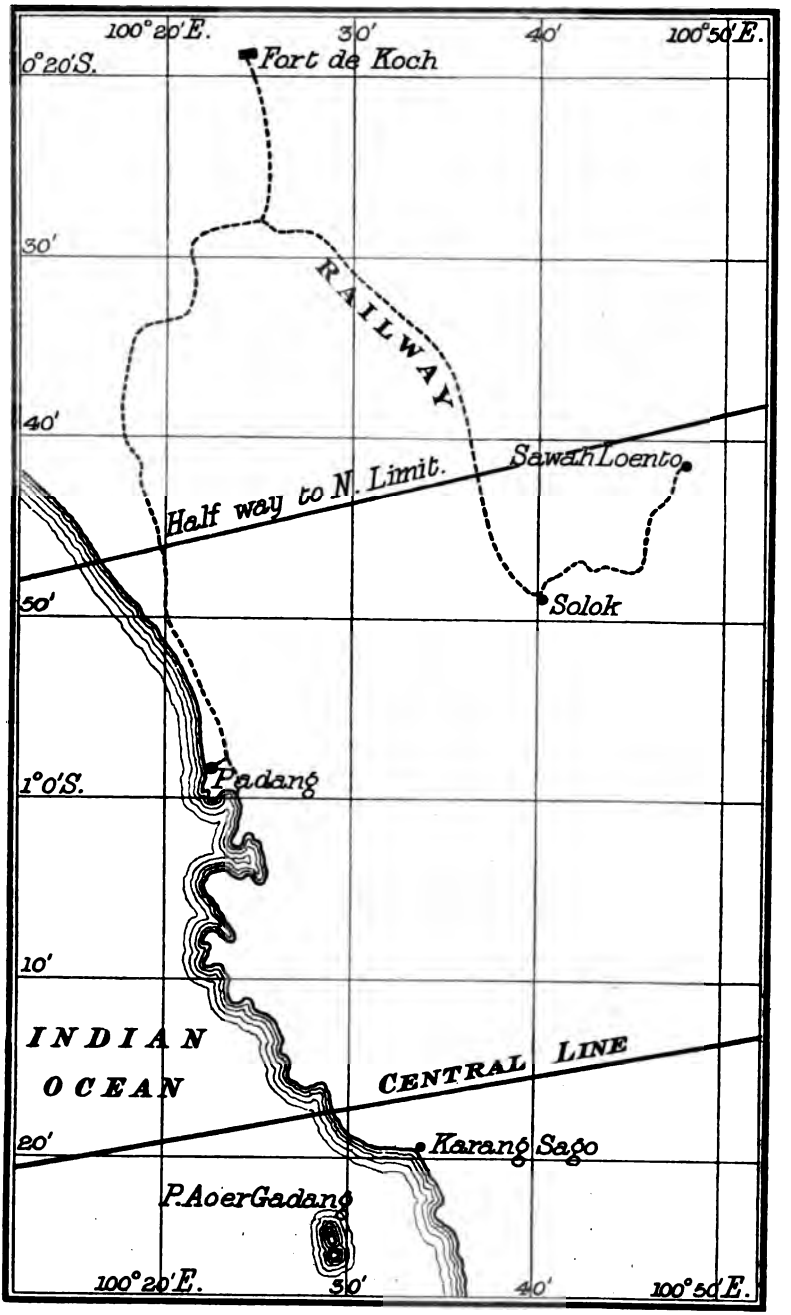
Padang, by the Lick Observatory party, French, Russian, and Japanese observers.

Karang Sago, by the Dutch party.

Aoer Gadang, by the Royal Observatory.

The presence of the "Pigmy" made it possible to occupy Aoer Gadang. This station had the advantage of being as far away as possible from the mountain range which runs parallel to the west coast of Sumatra. Solok and Sawah Loento are to the east of this range.

Aoer Gadang is a small island about 1 mile long and $\frac{1}{4}$ mile broad, surrounded by a coral reef. The site chosen for the eclipse camp was a small clearing near the eastern shore opposite a passage through the reef. Its position, as determined from large scale maps published by the Government of the Dutch East Indies, is lat. 1° 23′ 28″ S., and long. 100° 29′ 13″ E. of Greenwich. It is about 7 miles distant from


100° 20′ E.
30′
40′
100° 50′ E.
0° 20′ S.
Fort de Koch
30′
RAILWAY
40′
Sawah Loento
Half way to N. Limit.
Solok
50′
1° 0′ S.
Padang
10′
INDIAN
OCEAN
CENTRAL LINE
20′
Karang Sago
P. Aoer Gadang
100° 20′ E.
30′
40′
100° 50′ E.

d

the central line, 6 miles distant from the camp of the Dutch observers at Karang Sago, and 30 miles from Padang.

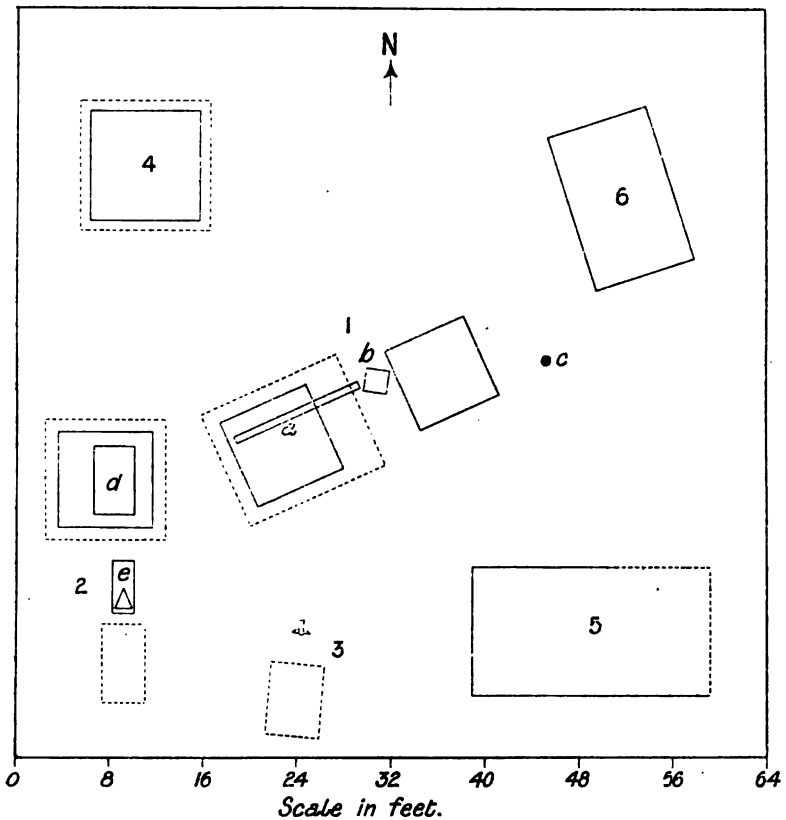
Erection of the Huts and Instruments.—The same light wooden frames covered with Willesden waterproof canvas which were used at Ovar in the eclipse of 1900, May 28, were taken out to Sumatra, with an additional one to serve as a developing room.* As a protection against sun and rain, these were supplemented by sheds, built in Malay style, of bamboos and thatched with *atap*, a species of palm leaf, which is obtained tied on laths about 4 feet long.

One open shed, 14 feet long and 12 feet broad, and 12 feet high at the gable, covered one of the two canvas huts and half of the second one, in which the Thompson coronagraph and the 16-inch cœlostat were placed. As at Ovar, the hut over the cœlostat was moved back a few feet during observations. Thatch was tacked on the roof of this hut. Similar sheds were fixed over the spectroscope hut and over the developing room. Thatch was also tacked all over the developing room hut. This, in addition to black waterproof paper inside, served to make the room light-tight. Movable sheds, each resting on four stout bamboos, were placed over the heliostat and condensing lenses of the spectroscopes and over the Dallmeyer photoheliograph. A house of bamboo and *atap* was also built, open on the east side and partly on the north, in which hammocks were swung, and where the observers lived at times when the "Pigmy" was obliged to leave for a short time. A tent was also erected for the two marines who were left on shore with the observers by Lieut. and Com. Oldham on such occasions. The general arrangement of the station is shown in the accompanying diagram. These huts, which were very satisfactory, were built under the superintendence of two Malay employés of Mr. Delprât, the Director of Railways.

The cœlostat was mounted on a concrete pier sunk about 18 inches into the ground, and rising 4 inches above it. The clock was screwed on to a box which was partly let into the ground, the weight being carried over a pulley on an iron bracket fixed on a palm-tree at a height of about 12 feet. The Thompson tube was mounted on boxes The table of the spectroscope was placed on four brick piers 4 feet high. The heliostat and condensing lenses were placed on a heavy box which rested on two rows of bricks, which raised it about 4 inches above the ground, the bricks being fixed on a bed of concrete. A foundation of brick and concrete was also provided for the Dallmeyer photoheliograph. In the building of the foundations, erection of piers, and putting together of the canvas huts we received every assistance from the officers and men of the "Pigmy," and are specially indebted to Lieut. Briggs and the engineer, Mr. Townsend. The erection of the huts and instruments occupied us till the beginning of May.

* 'Roy. Soc. Proc.,' vol. 67, p. 393.

PLAN OF ECLIPSE STATION AT AOER GADANG, 1901 MAY 18.



1. { *a*. Thompson coronagraph.
   b. Cœlostat.
   c. Palm-tree to which clock-weight was attached.
2. { *d*. Spectroscopes.
   e. Heliostat.
3. Double photographic camera.
4. Developing room.
5. Observer's house.
6. Men's tent.

Personnel.—The following list gives the names of those who took part in the observations:—

F. W. Dyson—Quartz spectroscope, Thompson coronagraph.

J. J. Atkinson—Flint spectroscope.

Lieut. and Com. Oldham—Double camera for small-scale photographs. Observed duration.

Lieut. Frewen—Gave signals of beginning and end of totality. Observation of stars.

Engineer Townsend—Set heliostat for corona spectrum, and again for second contact.

Surgeon Nimmo—Exposed at object glass of Thompson coronagraph. Observed duration.

Seven men from the "Pigmy" also assisted; two counting seconds with the aid of a metronome; one exposing in front of the condensing lenses for the spectroscope; one exposing in front of the object glasses of the double camera; and three assisting in handing plate holders to Mr. Dyson and Captain Oldham.

The mode of procedure, which was carefully rehearsed on several occasions previously, was as follows: The observers were stationed at their instruments, and Lieut. Frewen watched the diminishing length of the crescent of the sun on the ground glass of the coronagraph. He had a paper scale on which the lengths of the crescent were marked, computed at intervals of 3^m, 2^m, 1^m, 30^s, 20^s, 10^s before totality. At 3^m before totality Mr. Frewen called out "Stand by," and the metronome, which had been carefully rated, was started. At 1^m before totality he called out "Get ready." At the words "Thirty seconds" Mr. Dyson and Mr. Atkinson drew out the dark slides ready for exposure. At the word "Ten" the exposures for the "flash" spectrum were begun. At the word "Now" given at the moment of totality the time was recorded by Lieut. Oldham and Dr. Nimmo. Six seconds after totality Mr. Dyson and Mr. Atkinson changed the plates of the spectra and exposed for the corona spectrum, Mr. Townsend moving the image on the slit by the heliostat. Mr. Dyson then went to the Thompson coronagraph and made exposures as detailed below, while Lieut. Oldham exposed with the double camera. When the exposures with the Thompson were finished, about 30^s before the end of totality, Mr. Dyson returned to the spectroscope, where he and Mr. Atkinson changed the plates ready for the second flash, and Lieut. Frewen returned to the ground glass of the coronagraph, calling out "Now" at the instant of re-appearance, the times being noted as before by Lieut. and Com. Oldham, and by Surgeon Nimmo.

The Day of the Eclipse.—From May 1 to May 13 the weather was very fine in the early mornings, but the sky became overcast later in the day. On some of these days the observing conditions at the time of the eclipse were excellent, and on all were moderately good. On May 13, however, there was a heavy thunderstorm, and till May 17 the sky was generally overcast about noon. May 17 was a very wet day, and on May 18, the day of the eclipse, it was completely overcast at 6^h. At 8^h it began to clear, but during totality there was a good deal of light cloud in front of the sun. At 1 o'clock the sky was perfectly clear.

The following readings of the dry-bulb thermometer were taken on the day of the eclipse:—

	Local time. hrs.	mins.	secs.	Reading of thermometer. °
Beginning of eclipse	10	48	0	—
	11	0	0	88·8
	11	17	0	86·0
	11	30	0	85·0
	11	45	0	84·3
	12	0	0	81·8
	12	20	0	79·0
Beginning of totality	12	19	30	—
End of totality.....	12	26	50	—
	13	25	0	84·9
	13	40	0	84·9
	13	53	0	88·0
End of eclipse	13	58·	0	—

As the temperature usually rose from 90° to 92°, there would seem to have been a fall of temperature of from 10° to 13° due to the eclipse.

The duration of the eclipse was observed by Captain Oldham as $6^m\ 20^s{\cdot}5$, and by Dr. Nimmo as $6^m\ 21^s{\cdot}5$. These times agree with those obtained by the Dutch observers at Karang Sago, who give for the duration $6^m\ 22^s$.* These times are 10^s less than that given in the Nautical Almanac, but agree closely with a prediction kindly forwarded by Dr. Downing (based on a value of 15′ 31″·47 for the mean semi-diameter of the Moon, derived from a recent discussion of eclipse observations), viz., $6^m\ 20^s$.

At the commencement of totality at Aoer Gadang a signal was flashed across to the Dutch eclipse camp by the "Pigmy" search-light, thus giving them a warning 16^s before totality occurred at their station.

During totality the sky was much darker than at Ovar in the eclipse of 1900, May 28. Venus, Mercury, and Aldebaran were seen. The corona appeared to be white; the polar plumes and the prominences were distinctly seen.

Development of the Photographs.—As stated in a previous paragraph, a fully equipped dark room was taken out to Sumatra. It was found before the eclipse that considerable care was needed in the development of photographs owing to the high temperature. Immediately after the eclipse the "Pigmy" went to Padang, returning the next day with 250 lbs. of ice. The photographs were developed on May 19 and five following nights. Thanks to the untiring assistance of Mr. Curtain, gunner of the "Pigmy," the development of the thirty-seven

* 'Proceedings of the Koninklijke Akademie van Wetenschappen te Amsterdam, 1901,' p. 87.

photographs, which was a somewhat trying and arduous matter, was carried out very satisfactorily, only one failure of any consequence occurring.

II. *Photographs of the Corona.*

The programme of observations was composed of two distinct parts:

(1.) Photographs of the corona on a large scale to show structural detail.

(2.) Photographs on a smaller scale with rapid lenses, to show the coronal streamers with the greatest possible extension, and to photograph the sky round the Sun for the detection of an intra-Mercurial planet, should one exist.

(1.) *Large-scale Photographs.*—The instrument used was the Thompson photographic telescope with object glass of 9 inches aperture and 8 feet 6 inches focal length, belonging to the Royal Observatory, in combination with a concave telephoto lens by Dallmeyer, of 4 inches aperture and 16 inches focus, fitted as a secondary magnifier, to give an image of the sun 4 inches in diameter, with a field (for full pencils) of 14 inches. The total length of the coronagraph was 12 feet, the equivalent focal length being about 36 feet. The focus was determined by the method used by the Astronomer Royal at the eclipses of 1896, 1898, and 1900, by means of the image of a gauze net in the plane of the plate reflected from the plane mirror of the cœlostat.* In the determination of the focus, which was done at night, Mr. Curtain, warrant officer, rendered great assistance. A cœlostat, with 16-inch plane mirror (made by Dr. Common), was employed to reflect the rays into the coronagraph, which pointed downwards to the mirror at an angle of 3° or 4°, and was in the azimuth 18° north of east on the day of the eclipse. The adjustment of the cœlostat was readily made by observations of the Sun with the attached theodolite in the usual manner.

The camera was furnished with eight plate holders, to take 15 × 15 inch plates, or for the shorter exposures 12 × 10 inch plates in a carrier.

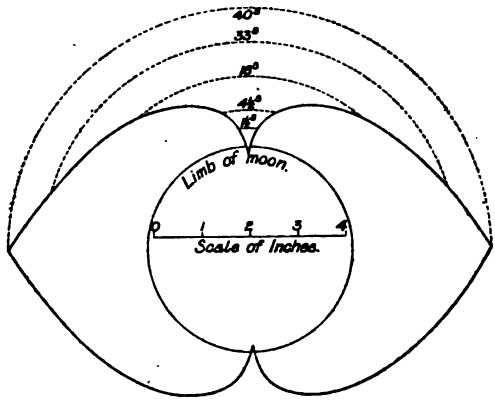
Two of the photographs were taken with a Burckhalter apparatus, made at the Royal Observatory, for graduating the length of exposure at different distances from the Sun's limb. For this purpose a zinc screen, whose form is shown in the diagram, and which was arranged to give what appeared to be suitable exposures at different distances (as shown by Professor Burckhalter's previous experience and Professor Turner's investigation of the diminution of the intensity of the coronal light) was rotated in front of the plate.

To accomplish this, photographic plates were obtained with a hole

* 'Monthly Notices, R.A.S.,' vol. 57, p. 105; 'Roy. Soc. Proc.,' vol. 64, vol. 67, p. 397.

in the centre $\frac{3}{4}$ inch in diameter, through which a spindle, mounted on the back of the plate carrier, was passed. On this spindle the screen was fixed in the dark room after the plate had been put in the carrier.

Occulting Shutter for Photographs of Corona by Burckhalter's Method.



The figures against the dotted lines show the effective exposures at different distances from the Sun's centre.

During the exposure, the observer turned a small handle about once a second, which, by a suitable train of wheels, caused the screen to turn about eight times a second. The apparatus appears to work perfectly smoothly, as the limb of the Moon is sharply defined on the photographs taken.

The eight slides were exposed as below, the exposures being made at the object glass by Dr. Nimmo:

	Exposure.			Plate.	
	Beginning.	End.	Duration.		
	m. s.	m. s.	secs.		in.
1	0 30	0 40	10	Mawson Photo-mechanical.	12 × 10
2	1 0	1 10	10	Edwards' Ordinary.	12 × 10
3	1 20	1 40	20	Ilford Empress.	15 × 15
4	2 0	2 40	40	,, ,,	15 × 15
5	2 50	3 30	40	Barnet Rocket.	15 × 15
6	3 40	3 45	5	Imperial Ordinary.	12 × 10
7	4 5	4 15	10	,, Sovereign	15 × 15
8	4 35	4 55	20	Wratten and Wainwright Ordinary.	12 × 10

A ninth plate was taken at 1 o'clock, local time, on which two exposures were made (the driving clock being stopped for two minutes between) for determination of the orientation of the plates.

"Abney" squares were printed on No. 6 when the plates were put in their carriers the night before the eclipse. The exposure given was 15^s to the light of a standard candle at the distance of 5 feet.

Of the eight photographs taken, the two by Burckhalter's method of an occulting shutter, are failures. The failure is not due to any fault in the method, but apparently is entirely owing to insufficient exposure, the corona photographed on the plates not extending as far as had been anticipated from previous eclipses. It seems probable that with a clearer sky these would have been quite satisfactory.

The other six photographs are excellent. The programme of exposures, which was carefully arranged with the Astronomer Royal before leaving England, has resulted in a well graduated series of photographs from No. 1, which shows the prominences and a small amount of corona to No. 5 in which the extension is shown to about 25′ from the Moon's limb. The polar plumes and the coronal streamers are well brought out, as well as the remarkable detail of the inner corona. Two features call for special note: (1) the polar streamers round the Sun's north pole are not nearly so extensive as those round its south pole; (2) a very remarkable arch in the corona round the large prominence at position angle 145° (measuring N.E.S.W.). Round this prominence three separate arches are shown, one inside the other, their radii being 1′·2, 2′·4, and 3′·7 respectively. They have the appearance of layers of clouds over an eruption.

(2.) *Small-scale Photographs to show Extension of the Corona.*—The double camera was used in this eclipse exactly as at Ovar to carry a Dallmeyer rapid rectilinear lens of 4 inches aperture and 34 inches focus working at *f*/8 (lent by the Royal Astronomical Society), and a "Unar" lens, by Ross, of 2·4 inches aperture and 12 inches focus, working at *f*/5.

Eight plate-holders, each taking a pair of 16 cm. × 16 cm. plates, were used during totality. The exposures, to avoid any possibility of shake, were made by holding a cover in front of the object glasses.

The mounting was exactly as at Ovar.

The exposures were as follows:—

No.	Duration. secs.	Plate.
1	5	Wratten and Wainwright Instantaneous.
2	20	Ilford Empress.
3	10	Imperial Ordinary.
4	35	Imperial Special Rapid.
5	20	Imperial Ordinary.
6	35	Imperial Sovereign.
7	5	Wratten and Wainwright Instantaneous.
8	10	Imperial Ordinary.

Abney squares were printed on No. 6 by exposure to a standard candle at a distance of 5 feet for 4 minutes with the Dallmeyer lens, and 8 minutes with the Unar lens. It had been intended to print squares on several plates, but the number of photographs to be dealt with made it necessary to limit work as much as possible the night before the eclipse when the photographic plates were taken from sealed tins and put in their carriers, and after the eclipse it was necessary to finish the developing as soon as possible. Of these photographs Nos. 5, 6, 7, 8 are the most successful. The extension shown with the Abney lens reaches to 66′ from the centre, and with the Unar lens to 77′.

Venus and Mercury and a number of stars are shown on the Unar plates. No. 5 is the best, and shows 7 stars of the Pleiades and 25 others of magnitudes ranging from 4 to 6, which have been identified. Unfortunately, owing to the clouds, stars are not equally well shown all over the plate, and δ Tauri ($4^m{\cdot}0$) and θ Tauri ($3^m{\cdot}9$) are not shown; γ Tauri ($3^m{\cdot}9$), which is near θ Tauri, is, however, shown.

It may be concluded that any object appreciably brighter than $4^m{\cdot}0$ within the area covered by the plate (*i.e.* within 15° of the Sun) would have been shown.

III. *The Spectroscopic Cameras.*

The two spectroscopes used by Captain Hills at the Indian Eclipse of 1898 were kindly lent by him, and were used in Sumatra with the following adjustments:—

	Spectroscope No. 1.	Spectroscope No. 2.
Objective	Cooke, achromatic, 4½-in. aperture, 6-ft. 2½-in. focus.	Single quartz lens, 5-in. aperture, 4-ft. 7-in. focus.
Collimator and camera lenses	Single quartz lens, 2½-in. aperture, 30-in. focus.	Single quartz lens, 3-in. aperture, 33½-in. focus.
Prisms	Two dense flint prisms of 60°, 4½-in. base, 2½-in. height.	Four double quartz prisms of 60° (each prism being composed of two half-prisms of right- and left-handed quartz), 3½-in. base, 2½-in. height.
Slit	1½ in. by 0·0015 in.	2 in. by 0·0012 in.
Prisms at maximum deviation for	H (λ 4340)	λ 3500.

The width of the slit of the flint spectroscope was obtained by means of the diffraction images, and that of the quartz was checked in the same manner.

The length of the spectrum of the flint is 3¼ inches from H_β

(λ 4861) to K (λ 3934), and for the quartz 3 inches from λ 4000 to λ 3300. In order to obtain a greater length of spectrum in focus, the plate holders were made, at Mr. Davidson's suggestion, to carry two plates 3¼ inches wide, inclined at a suitable angle, instead of one 6½ inches wide.

Both spectroscopes were mounted horizontally, and supplied with light by a heliostat furnished with a 12-inch flat mirror. The heliostat was adjusted in the usual manner by means of the attached theodolite.

Programme of Exposures.—The two spectroscopes were adjusted to be as nearly as possible on the Sun's limb simultaneously, and the programme of exposures was the same for both. The cameras were provided with rack movements so that a number of exposures could be made on the same plate. The programme arranged to take—

(i.) A number of short exposures from 10ˢ before to 6ˢ after the beginning of totality for the "flash" spectrum.

The plate carriers were then changed, and

(ii.) An exposure for the spectrum of the corona made from 15ᵐ or 20ˢ after the beginning of totality, and continued for 5½ minutes—the exposure ending at 5ᵐ 50ˢ from the beginning of totality.

The plate carriers were again changed, and

(iii.) From 6ᵐ 10ˢ from the beginning or 10ˢ from the end of totality, exposures were to be made for the "flash" at third contact.

Between (i) and (ii) the image of the Sun was to be brought by the slow motion of the heliostat from being nearly tangential to the slit to a position in which the horizontal diameter was divided by the slit in a ratio of 1 : 3. Again, between (ii) and (iii) it was to be brought nearly tangential.

A hitch occurred between (ii) and (iii), and the "flash" at second contact was not obtained.

The plates used for the "flash" at the beginning of totality were Edwards' Isochromatic and Ilford Empress for the flint spectroscope, and Ilford Empress for the quartz.

For the corona, "Snap-shot," Isochromatic, and Rocket plates were used for the flint spectroscope, and Imperial Special Rapid for the quartz.

The Corona Spectrum.—The continuous spectrum of the corona is shown from D_3 (λ 5876) to λ 3350. The green line at 5304 is strongly shown. The lines at 4568, 4233 and 3987 are shown. No new lines are shown. In the ultra-violet the lines at 3801, 3456 and 3381 are strongly shown, and possibly some fainter lines. The wave-lengths have not yet been determined accurately. No absorption lines are shown.

The Chromospheric Spectrum.—This is obtained on the different plates extending from D_3 (λ 5876) to a little beyond 3300. The photographs are not on the whole so good as those obtained at Ovar, but will serve

to supplement at the two ends of the spectrum, 70 lines being shown between Hβ (λ 4861) and D_3 (λ 5876), and 100 between 3500 and 3296.

"Total Eclipse of the Sun, 1901 May 18. Preliminary Account of the Observations made at the Royal Alfred Observatory, Pamplemousses, Mauritius." By E. WALTER MAUNDER, F.R.A.S. Received October 24,—Read at Joint Meeting of the Royal and Royal Astronomical Societies, October 31, 1901.

General Arrangements.

An expedition from the Royal Observatory to observe the Solar Eclipse of 1901 in the island of Mauritius having been sanctioned by the Admiralty, I was instructed by the Astronomer Royal to proceed to that island, there to act in concert with the Director of the Royal Alfred Observatory, Mr. T. F. Claxton, who had expressed his desire to co-operate in the observation of the eclipse. In accordance with a scheme approved by the Joint Permanent Eclipse Committee of the Royal and Royal Astronomical Societies, I took out with me two instruments belonging to the Royal Observatory, Greenwich, for photographing the corona; the one giving an image of the Moon 2·4 inches in diameter, and intended to secure the general structure of the corona, and the other giving an image 0·3 inch in diameter, and intended to secure the outer coronal streamers. The Joint Permanent Eclipse Committee lent for use in combination with these instruments two cœlostats, the one carrying a mirror of 16 inches diameter, the other one of 12 inches. A third mirror, one of 12 inches diameter, was kindly lent by Mr. Frank McClean, F.R.S. My equipment was completed by the generosity of Mr. John Evershed, F.R.A.S., who very kindly placed his prismatic camera of 2 inches aperture at the disposal of the Astronomer Royal for my use in the eclipse.

I was warmly welcomed in Mauritius by the Director of the Royal Alfred Observatory, Mr. T. F. Claxton, and by his Chief Assistant, Mr. A. Walter. Both identified themselves completely with me in my work, and helped me in every possible way. We therefore combined the instruments which I had brought out with those of the Observatory, and worked with them as though we formed but one party, and as if the instruments were all part of the same equipment.

I was also greatly indebted to Sir Charles Bruce, G.C.M.G., the Governor of the island, and to Sir Graham Bower, K.C.M.G., the officer administrating the Government during the Governor's absence, for the ready hospitality which they extended to me. Through their action, also, my instruments were landed without Customs examina-

tion and were conveyed by rail, free of cost, up to Pamplemousses, and back again after the eclipse was over. Free passes on all the railways of the island were also issued to me, and to Mrs. Maunder, who had accompanied me with a special instrumental equipment of her own. The military authorities also rendered great assistance. Lieutenant-Colonel H. J. Lyster, R.G.A., gave permission to nine non-commissioned officers of the garrison, who had volunteered for the purpose, to come down to assist in the eclipse observations. Of these, five also helped in the unpacking and erection of the instruments, and one, Staff-Sergeant R. M. Smith, A.O.C., gave great assistance in the cleaning, repair, and rating of the several driving-clocks. The expedition was also indebted to the Hon. Hamilton Stein, who undertook the re-shipping of the instruments for the homeward voyage; to Mr. G. Ireland, who supplied tarpaulins for covering the skeleton huts erected to shelter the instruments; to Captain A. W. de Wilton, Inspector-General of Police, who sent constables to keep the Observatory grounds from intrusion on the morning of the eclipse, and to Mr. D. P. Garrioch, Superintendent of Inland Revenue, who arranged for the greater part of the provisioning of the eclipse party during their stay at the Observatory.

Itinerary.—The instruments for the Mauritius expedition were despatched from the Royal Observatory on March 6, with the exception of the prisms and object-glass of the prismatic camera lent by Mr. John Evershed, F.R.A.S., which I took to Marseilles with my personal baggage. The instruments were embarked at the Royal Albert Docks on the ss. "Bagdad" of the Messageries Maritimes line, and transhipped from that vessel to the ss. "Melbourne" of the same line at Marseilles. I left London on March 23, and proceeded overland through France to Marseilles. Owing to the great dock strike then prevailing at Marseilles, the ss. "Melbourne" was not able to leave until the evening of March 26. The delay was, however, made up for by greater speed on the voyage, and Mauritius was reached on April 20, as had been originally expected. The return voyage was unexpectedly delayed, as the Messageries line quarantined the island on account of the plague there, and the Union-Castle steamers having ceased to run to Mauritius, in consequence of the South African war, the British India line *viâ* Colombo was the sole remaining homeward route, and even on this line the steamers only ran once a month. It was not possible, therefore, to leave Mauritius again until July 12, when I embarked on the ss. "Warora"; reaching Colombo on July 22. Here I had to wait until July 25, when I left by the ss. "Mombassa," also of the British India line, and reached London August 25. The instruments left Mauritius in the ss. "Slingsby" on July 12, and were received at the Royal Observatory, Greenwich, on September 10.

Station.—The station occupied was the Royal Alfred Observatory,

Pamplemousses, in the low-lying plain which occupies the north of the island of Mauritius. This was about 15 miles to the N.W. of the central line, but as the eclipse was one of long duration, the distance from the central line made but little difference to the length of totality, and several important considerations led to its adoption. First of all, the probabilities of fine weather at the time of the morning when the eclipse would take place, appeared much greater for the low ground in the north of the island, than for the hills in the centre; an anticipation which the event fully justified; for whilst the total phase of the eclipse was observed under favourable conditions at Pamplemousses, it was entirely lost in cloud at Curepipe, on the central line on the high ground in the interior. Next, there were the great advantages offered by the Observatory itself of accurate determination of time, of a site the co-ordinates of which were known, of two instruments on permanent mountings, an equatorial and a photoheliograph, suitable for use in the eclipse, and of two efficient and well constructed dark-rooms for photography.

The observing station was therefore fixed in the Observatory grounds, in Lat. 20° 5′ 39″ S. and Long. $3^h\ 50^m\ 12^s{\cdot}6$ E. according to the "Nautical Almanac," on the authority of the late Dr. C. Meldrum, the former Director.

Erection and Arrangement of the Instruments.

The instruments were landed from the "Melbourne" at Port Louis, on April 23, and were conveyed by rail to Pamplemousses, and from thence by road to the Observatory, the same day. The next day they were unpacked, and the positions which they were to occupy were chosen.

The main building of the Observatory is rectangular in form, and nearly but not exactly orientated. Its front or north side is 76½ feet in length, and its breadth is 58½ feet. Opposite the north front and distant from it 160 feet, is the Magnetic Basement, a structure of which only the roof is above the ground, and which is 43 feet square. A broad lawn extends between the two buildings, and the instruments were erected for the most part at the west end of the lawn, so as to command as much of the eastern sky as possible. It was, however, found necessary to cut down a clump of trees on the eastern side of the lawn to a height of 16 feet in order to secure an uninterrupted view of first contact, which would take place when the sun was only 5° high, and this Mr. Claxton accordingly had done.

The instruments were mounted in two divisions. The first division consisted of the Mauritius photoheliograph, which was dismounted from its equatorial stand in a detached dome in the Observatory grounds, and of a rapid rectilinear lens by Dallmeyer, of 4 inches

aperture and 32 inches focal length. These two instruments were placed horizontally, the camera of the R.R. lens being placed immediately above the photoheliograph tube, and both were supplied with light by means of a 16-inch mirror mounted on a cœlostat. The second division consisted of the Greenwich coronagraph, and Mr. Evershed's prismatic camera. The coronagraph was mounted in a horizontal position, and the prismatic camera was fixed immediately above it, both instruments being supplied with light by a 12-inch mirror mounted on a cœlostat. Between the two a clock was mounted which rang an electric bell close to the camera end of the photoheliograph, and another close to the 12-inch cœlostat, at every tenth second during totality. The instruments were fixed upon boxes filled with stones, and to shelter them skeleton huts were formed, each consisting of three pairs of poles carrying a ridge-pole. Tarpaulins were then thrown over the ridge-pole, and pegged down to the ground. When any instrument needed to be used, one or more of the tarpaulins could be thrown up on the side upon which it was desired to observe. During the eclipse all the tarpaulins were entirely removed, except one fixed round the 10-second clock, which was left in order to shelter the pendulum from the wind.

The positions of the instruments relative to the Observatory buildings are shown in the accompanying plan, in which are also indicated the positions of Mrs. Maunder's instruments, which were also set up in the Observatory grounds.

The above arrangement of the instruments was finally completed by May 11 when the prismatic camera was mounted, one week before the eclipse.

Personnel.—The following list gives the names of those who took part in the observations:—

With the 16-inch cœlostat and its telescopes—

T. F. Claxton—Mauritius photoheliograph. Large-scale photographs of inner corona.

Bombardier A. J. Cox—Recorder to Mr. Claxton.

Bombardier C. A. Truman—Carried plate-holders for Mr. Claxton to and from dark-room during the partial phase.

Charles G. Garrioch—Changed the plates in the plate-holders during the partial phase.

T. A. Pope—Rapid rectilinear lens. Small-scale photographs to show extension.

E. G. Rowden—Exposed at the object-glasses of both the photoheliograph and the R.R. lens for Mr. Claxton and Mr. Pope.

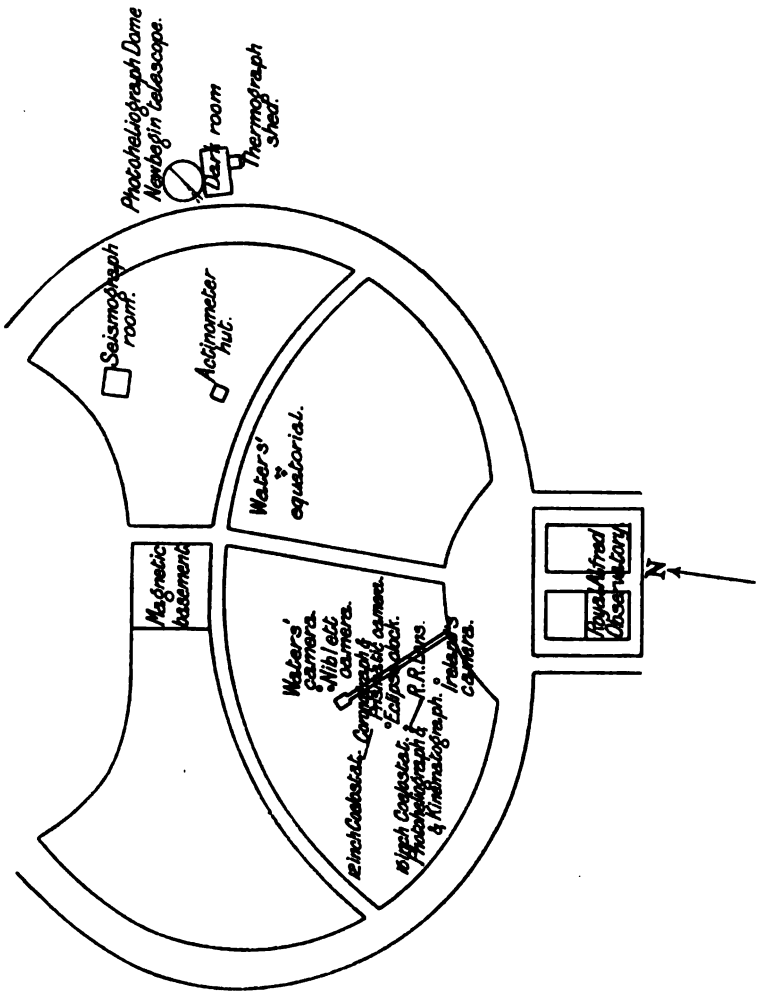
With the 12-inch cœlostat and its telescopes:—

E. Walter Maunder—Greenwich coronagraph. Large scale photographs of corona.

Lance-Corporal Lilley—Recorder to Mr. Maunder.

Bombardier W. Bailey—Moved rack-work of the Evershed prismatic camera.

Colour-Sergeant-Major W. Wade—Exposed at the object-glasses of both the coronagraph and the prismatic camera.



Plan of the Grounds of the Royal Alfred Observatory, Mauritius, showing the distribution of the Instruments during the Total Solar Eclipse of 1901, May 18.

With the 10-seconds eclipse clock :—

Staff-Sergeant R. M. Smith—Time-keeper at 10-second clock.

F. W. Robertson, Lieutenant, R.E.—Recorded times of the 10-second signal-bells.

With the 6-inch equatorial of the Mauritius Observatory :—
F. T. Piggott—Observed with the 6-inch equatorial.
N. V. Olivier—Recorder to Mr. Piggott.

The following was the method of procedure, which was carefully rehearsed many times on May 16 and 17. The observers took their places at their instruments, and Mr. Claxton watched the diminishing arc of the Sun on the ground glass of the photoheliograph, and at 30 seconds before second contact gave the word to "Stand by." At 20 seconds I gave the word to Sergeant-Major Wade to begin the exposure of the plates in the prismatic camera. At 10 seconds, when the arc of sunlight had lessened down to one of 49°, Mr. Claxton called "Ten," the signal to Staff-Sergeant Smith to start the 10-seconds striking eclipse clock, and Staff-Sergeant Smith called the number of the bells as they rang out at every tenth second from this moment until some time after third contact. The exposures at the different cameras were then made at the sound of the bells, and Lieutenant F. W. Robertson, R.E., entered the time of each bell as it rang; a very simple arrangement, which worked smoothly and well, and gave the times of exposure of the different plates very closely.

The Day of the Eclipse.—The weather at eclipse time—*i.e.*, from $6^h\ 51^m$ to $9^h\ 5^m$ A.M.—had been by no means promising for the first three weeks after landing, but had tended to improve later. The morning of May 18 was the first upon which the Sun had been entirely free from cloud at the time of totality, $7^h\ 53^m$ A.M., and even on that morning first contact was lost by the interposition of a dense bank of cloud, which came up from the east soon after sunrise and overtook the Sun. It passed away in a few minutes, and the first photograph of the partial phase was taken at 16 minutes after the predicted time for first contact. Light scud continued to pass over the Sun for about 40 minutes more, but got thinner and lighter as totality drew on, and about $2\frac{1}{2}$ or 3 minutes before second contact the entire eastern half of the sky was free from cloud, and remained so until after fourth contact. But though the sky was thus apparently clear there was evidently much moisture in the air, since at Quatre Bornes, 13 miles to the south-west, the total phase was observed in a smart drizzle of fine rain; and at Curepipe, 16 miles to the south, it was entirely lost by thick cloud. The images also, as seen upon the ground glasses of the photoheliograph and coronagraph, were very unsteady, the Sun's limb "boiling" excessively. This "boiling" effect would seem to have been less noticeable in the 6-inch equatorial mounted in a dome on the roof of the Observatory main building, and in the Newbegin telescope brought by Mrs. Maunder and mounted in the photoheliograph dome of the Observatory, and which were therefore at a considerable elevation than in the instruments fed by the two

cœlostats which were necessarily quite close to the ground. The position of the latter, in the open air and placed horizontally, would render them more exposed to the effect of ground currents than the two other telescopes would be, pointing upwards at an angle of 19° and within domes.

The darkness during totality to the observers out in the open air was not great, the general illumination being considerably greater than at the full Moon. Five observers, noting the twilight illumination in the evening after the eclipse, considered it equal to that of mid-totality at the following local times:—

	h.	m.	
Mrs. Claxton	5	58	P.M.
Mrs. Maunder	5	57	
Mr. Claxton	5	58	
Mr. Hall	5	58	
Mr. Maunder	5	57	

corresponding in the mean to 31 minutes after geometrical sunset, or to a position of the Sun, neglecting refraction, of 6° 53′ below the horizon.

But the observers in the equatorial and photoheliograph domes found it very dark during totality. A sudden gust of wind came from the N.E. at the moment of second contact and blew out the observer's candle in the equatorial dome. The recorder here, Mr. Olivier, found it quite impossible to read his chronometer or to write in the darkness, and hence Mr. Piggott's determination of the times of the second and third contacts were wholly lost.

Venns and Mercury were both very brilliant, side by side, some 5° below the Sun, whilst Jupiter and Saturn were prominent in the western sky. No search was made for other celestial objects.

Times of the Contacts.—The following determinations were made of the times of the three last contacts. As already stated, the first contact was lost through cloud:—

Observer	T. F. Claxton.	E. W. Maunder.	A. Walter.	Capt. Robertson.
Place	R. Alfred Obs.	R. Alfred Obs.	R. Alfred Obs.	ss. "Ugina."
Instrument	Photoheliograph	Coronagraph.	Newbegin telesc.	Navy telescope.
Aperture	4 in.	4 in.	4¼ in.	2 in.
Chronometer	Kullberg 3400.	H. White 1424.	Webster 925	
Error of chronometer	$1^m\ 0^s{\cdot}4$ f.	$3^h\ 53^m\ 47^s{\cdot}3$ s.	$2^m\ 58^s$ s.	
Observed times—				
Second contact.	..	3 57 52·2	$7^h\ 48^m\ 43^s$	
Third contact..	..	4 1 25·1	7 52 15	
Fourth contact	$9^h\ 5^m\ 43^s{\cdot}0$	5 10 55·1		
True local times—				
Second contact.	..	7 51 39·5	7 51 41	$7^h\ 51^m\ 38^s$
Third contact..	..	7 55 12·4	7 55 13	7 55 12
Fourth contact	9 4 42·6	9 4 42·4		

Captain Robertson was not present at the Royal Alfred Observatory, but observed the eclipse from the deck of his ship, ss. "Ugina," of the British India Steam Navigation Company, in Port Louis harbour, 6½ miles S.W. by W. of the Observatory.

An accident prevented Mr. Claxton from observing the second and third contacts. Mr. Claxton and myself watched the contacts on the ground-glass screens of our respective cameras.

Times of the 10-second Bells.—The times of the 10-second bells of the eclipse clock—which was one of the clocks used by the late Sir G. B. Airy, K.C.B., in the Harton Colliery experiment—were recorded by Lieutenant F. W. Robertson, R.E., with the chronometer Kullberg 3400, that chronometer being $1^m\ 0^s{\cdot}4$ fast.

No. of Bell.	Observed time.	True local time.
	h. m. s.	h. m. s.
1	7 52 42·3	7 51 41·9
2	52·3	51·9
3	53 2·3	52 1·9
4	12·2	11·8
5	22·1	21·7
6	32·1	31·7
7	41·9	41·5
8	51·9	51·5
9	54 1·8	53 1·4
10	11·8	11·4
11	21·8	21·4
12	31·7	31·3
13	41·8	41·4
14	51·8	51·4
15	55 1·8	54 1·4
16	11·8	11·4
17	21·7	21·3
18	31·7	31·3
19	41·7	41·3
20	51·8	51·4
21	56 1·6	55 1·2
22	11·6	11·2
23	21·6	21·2
24	31·6	31·2

Staff-Sergeant R. M. Smith called out the numbers of the bells as each rang.

Photographs of the Corona.—These were taken on three different scales; the first on a scale of 8 inches to the Moon's diameter, to show the prominences and lowest corona; the second on a scale of 2·4 inches, to show the general structure of the corona; the third on a scale of 0·3 inch, to show the coronal streamers to the greatest possible extension. The aperture employed in each case was the same, viz., 4 inches, and the light-gathering powers on the plate of the three instruments were nearly in the proportion of 1, 11, and 700.

(1.) *Photographs on the 8-inch Scale.*

These were taken by Mr. T. F. Claxton with the photoheliograph of the Royal Alfred Observatory, Mauritius, the object-glass of which is 4 inches in aperture and 5 feet in focal length. It gives an image of the Sun nearly 8 inches in diameter, being fitted with a secondary magnifier, enlarging the image in the primary focus $13\frac{3}{4}$ times. The total length of the photoheliograph was $9\frac{1}{2}$ feet; its equivalent focal length 69 feet. The camera was constructed to carry plates 10 inches square, and it was proposed to expose six plates during totality for photographs of the corona, and as many as possible during the partial phase for determination of the Moon's place, and of the relative diameters of the Sun and Moon. Only three plates were exposed during totality, the handle of the shutter of the fourth plate-carrier breaking short off when the shutter was opened. The plate-carrier was thus locked in the camera, and it was not possible to release it until the total phase was over. The three plates taken were exposed as below, the exposures being given by Mr. Rowden at the object-glass of the instrument at the sound of the signal bells.

No.	From	To	Duration of exposure.	Plate.
			sec.	
1	Bell 3	Bell 5	20	Edwards' Medium.
2	,, 6	,, 8	20	Imperial Ordinary.
3	,, 8	,, 11	20	,, Special Rapid.

After totality the clock of the cœlostat was stopped, and three photographs of the Sun were taken on the same plate for orientation. The true local times of the first and last of these were :—

h.	m.	s.
8	15	20·1
8	16	5·2

The time of the second exposure was not recorded. The plate was an "ordinary lantern" by Cadett and Neale. The aperture of the photoheliograph was reduced to $1\frac{1}{2}$ inches, and the exposure was given by the drop-slit in the primary focus.

Two sets of "Abney squares" were printed upon No. 3 on June 13, before the plate was developed. Both sets were printed by the light of a Sugg's Standard candle; the one being exposed for 4 seconds, the other for 64 seconds, the candle being at a distance of 10 feet in both cases.

The corona is seen only on the E. side of the Sun, as the image is

somewhat out of the centre of the plate in all three of the photographs; and owing partly to shake in the instrument, and partly to the excessive atmospheric disturbance, which under the high magnification employed was very apparent, the definition is poor in each case.

No. 1. The corona is shown to a height of about 1 minute of arc. The image is faint.

No. 2. The corona is shown to a height of about 3 minutes of arc. The image is fairly dense.

No. 3. The corona is shown to a height of about 2 minutes of arc. The image is faint and flat.

The Mauritius photoheliograph was focussed by repeated photographs of the Sun, taken during the fortnight preceding the eclipse.

(2.) *Photographs on the 2·4-inch Scale.*

These were taken with the object-glass of the Dallmeyer photoheliograph No. 5, belonging to the Royal Observatory, Greenwich —and which, like that of the Mauritius photoheliograph, had an aperture of 4 inches and a focal length of 5 feet—used in connection with a concave telephoto lens by Dallmeyer, of 3 inches aperture and 12 inches focal length. The instrument thus constructed has been referred to for convenience as the "Greenwich coronagraph," and was about 7½ feet in actual length, with an equivalent focal length of nearly 21 feet. It was furnished with ten plate-holders to take 12 by 10-inch plates, and it was proposed to take seven photographs during totality.

These photographs were taken by myself, Colour-Sergeant-Major Wade exposing at the object-glass of the instrument by the signal bells as follows:—

No.	From	To	Duration of exposure.	Plate.
			secs.	
1	Bell 2	Bell 3	10	Wratten and Wainwright Instantaneous.
2	„ 4	„ 6	20	Ilford Empress.
3	„ 7	„ 11	40	Imperial Special Rapid.
4	„ 12	„ 15	30	„ Sovereign.
5	„ 16	„ 18	20	„ Fine Grain Ordinary.
6	„ 19	„ 20	10	„ Special Rapid.
7	„ 21	—	4	„ Ordinary.

After the ground glass had been inserted for the observation of third contact, and had been removed again, the aperture was diminished to half an inch, and the clock of the cœlostat stopped and three photo-

graphs were taken of the Sun, on the same plate for orientation. The plate was an Imperial Fine Grain Ordinary and the exposure was as quick as could possibly be given by uncovering and covering the object-glass by hand. The true local times of the three exposures were :—

h.	m.	s.
7	58	39·3
7	58	57·3
7	59	17·3

A ninth plate, a Wratten and Wainwright Instantaneous plate, was exposed with the same aperture and exposure at $8^h\ 0^m\ 17^s{\cdot}3$. The plate in the tenth plate-holder was not used.

Two sets of "Abney squares" were printed upon No. 4 on June 13, before the plate was developed. Both sets were printed by the light of a Sugg's Standard candle, at 5 feet distance; the one being exposed for 15 seconds, and the other for 4 minutes.

No. 1 is a clean and fairly dense negative, showing well the polar rays and the structure of the lower corona, especially in the east equatorial wing. The west wing shows less detail. The corona is traceable to a distance of 15 or 16 minutes from the limb of the Moon in the S.E. ray.

No. 2 is a clear thin negative showing much about the same detail as No. 1.

No. 3 is a thin negative but shows a considerable extension of the great S.E. and N.E. rays and a good deal of detail in their lower regions.

No. 4 is a dense negative showing the greatest degree of extension in the coronal streamers of any of the series. In the case of the two chief rays, the corona can be traced to a distance of nearly half a degree from the Moon's limb.

No. 5 shows the lower corona well up to 5 or 6 minutes from the Moon's limb.

No. 6 is partly spoiled by fog, and only the lower corona is seen up to about 3 minutes.

No. 7 is a faint and delicate negative showing the chromosphere, prominences, and the lower corona up to a distance of about 3 minutes from the limb of the Moon.

Two methods were employed to focus the Greenwich coronagraph; the first being the method described by the Astronomer Royal in his Reports of the Eclipse Expeditions of 1896, 1898, and 1900,* an image of an object (gauze net in the plane of the plate) being photographed by reflection normally from the plane mirror of the cœlostat. The second method was by photographing Arcturus, the image of which was allowed to trail across the plate.

* 'Roy. Soc. Proc.,' vol. 64, p. 8; and 'Monthly Notices, R.A.S.,' vol. 57, p. 105, and vol. 60, p. 397.

(3.) *Photographs on the 0·3-inch Scale.*

These were taken by Professor T. A. Pope, of the Royal College, Mauritius, with a Dallmeyer rapid rectilinear lens of 4 inches aperture, and 32 inches focal length, Mr. E. G. Rowden exposing at the object-glass at the same time as he exposed for the Mauritius photoheliograph, which was mounted immediately below it. Six plate-carriers were provided for this instrument, and six photographs of the corona were secured.

No.	From	To	Duration of exposure.	Plate.
			sec.	
1	Bell 3	Bell 5	20	Imperial Process.
2	,, 6	,, 8	20	,, Ordinary.
3	,, 9	,, 11	20	,, Special Rapid.
4	,, 12	,, 14	20	Ilford Empress.
5	,, 15	,, 17	20	Wratten and Wainwright Instantaneous.
6	,, 18	,, 20	20	Imperial Fine Grain Ordinary.

The plates used were 16 cm. square, and the Sun was placed a little to the west of the centre of the field, so that Venus and Mercury might be included in the photographs. As they are well shown on all the plates, there was no need for any other mode of orientation, and no special photographs were taken for that purpose. Nor were the "Abney squares" printed on any of the plates with this instrument.

No. 1. A good clear negative. On the west side of the corona four straight rays are seen, the two longest extending about $1\frac{1}{4}^{\circ}$ from the Moon's limb. On the east two chief rays are seen, forming the edges of the great east equatorial wing of the corona. A fainter ray runs nearly parallel to the great N.E. ray. The rays on the E. are traceable to about 1° from the Moon's limb.

No. 2. Neither so dense nor so clear as No. 1, nor can the rays be traced quite so far upon it.

No. 3. The sky glare has come up on this plate, which in consequence shows less than Nos. 1 and 2.

No. 4. Definition poor.

No. 5. Definition poor.

No. 6. Very dense image; the rays on the west can be traced to more than 2° from the Moon's limb.

The Dallmeyer R.R. lens was focussed by repeated photographs of star fields, especially of the field of the Southern Cross.

Development of the Photographs.—Owing to my having been taken ill on May 21 with a severe attack of malarial fever, the work of

developing the photographs was almost entirely carried out by Mr. Walter and by Mrs. Maunder, to whom the expedition is therefore greatly indebted for the results obtained. The weather being hot and damp, much difficulty was experienced with the different plates tested by way of experiment before the day of the eclipse. Finally the following developer was adopted and found to work well. In spite of its excessive dilution, it was found that fog resulted if its strength was materially increased.

Solution A.

Metol	40 grains.
Hydroquinone	50 ,,
Sulphite of soda	120 ,,
Bromide potassium	15 ,,
Water	20 ounces.

Solution B.

Caustic soda	100 grains.
Water	20 ounces.

For development half an ounce was taken of each stock solution and made up with water to 30 ounces, 15 drops of a 10 per cent. solution of bromide of potassium being added. During development this solution was strengthened by the gradual addition to it of a solution composed of 1 ounce of each of the two stock solutions made up with water to 10 ounces. But the stronger solution was seldom added to the weaker in a greater proportion than 1 to 15. The average time of development was 75 minutes.

Photographs of the Partial Phase.—These were taken with the photo-heliograph of the Royal Alfred Observatory, Mauritius, already described. The aperture for this purpose was reduced to $1\frac{1}{2}$ inches, and the exposure given by the drop-slit in the primary focus. Mr. T. F. Claxton made the exposures, and called the times by Kullberg 3400 to Bombardier Cox, who entered them. There being only three plate-carriers available for this work, Mr. C. Garrioch remained in the dark room to change the plates, and Bombardier Truman ran to and fro with them. The plates used were Cadett and Neale's ordinary lantern plates. The times of exposure were as follows :—

Before Totality.

No.	Observed times.			True local times.		
	h.	m.	s.	h.	m.	s.
1	7	8	19·8	7	7	19·4
2	7	10	19·8	7	9	19·4
3	7	14	5·3	7	13	4·9
4	7	18	1·3	7	17	0·9
5	7	22	46·3	7	21	45·9
6	7	28	47·3	7	27	46·9
7	7	31	7·8	7	30	7·4
8	7	35	6·2	7	34	5·8
9	7	38	47·3	7	37	46·9
10	7	42	43·0	7	41	42·6
11	7	44	32·4	7	43	32·0

After Totality.

12	8	2	48·8	8	1	48·4
13	8	3	43·3	8	2	42·9
14	8	11	44·5	8	10	44·1
15	8	12	41·0	8	11	40·6

Plate 16 had three exposures made upon it, the clock of the cœlostat being stopped in order to give the means for determining the orientation of the plates.

No.	Observed times.			True local times.		
	h.	m.	s.	h.	m.	s.
17	8	19	40·0	8	18	39·6
18	8	22	34·3	8	21	33·9
19	8	24	25·7	8	23	25·3
20	8	26	44·3	8	25	43·9
21	8	31	28·6	8	30	28·2
22	8	32	33·2	8	31	32·8
23	8	34	40·5	8	33	40·1
24	8	36	24·5	8	35	24·1
25	8	39	56·3	8	38	55·9
26	8	42	7·5	8	41	7·1
27	8	45	13·2	8	44	12·8
28	8	48	15·4	8	47	15·0
29	8	50	33·7	8	49	33·3
30	8	53	8·2	8	52	7·8
31	8	54	5·0	8	53	4·6
32	8	59	50·2	8	58	49·8

The Director of the Royal Alfred Observatory has presented to the Astronomer Royal the photographs of the eclipse which he took with

the Observatory photoheliograph, both the photographs which he took of the corona during totality and the above photographs of the partial phase. The former I myself brought home to the Royal Observatory, Greenwich; the latter will be sent at the first available opportunity.

I took no observations myself of temperature during the eclipse, the Director of the Royal Alfred Observatory having made arrangements for full meteorological observations being taken both at the Observatory and at several other stations, not only in Mauritius, but also on other islands in the Indian Ocean.

"Preliminary Note on Observations of the Total Solar Eclipse of 1901 May 18, made at Pamplemousses, Mauritius." By (Mrs.) A. S. D. Maunder. Received October 23,—Read at Joint Meeting of the Royal and Royal Astronomical Societies, October 31, 1901.

Having observed successfully the eclipses of 1898 January 22, in India, and 1900 May 28, in Algiers, and my husband having been sent to Mauritius as the representative of the Royal Observatory, Greenwich, to observe the eclipse of May 18 last, I determined to accompany him, and to take with me the instruments which we had used in 1900. By the great kindness of Mr. G. J. Newbegin, F.R.A.S., I was also furnished with a 4¼-inch Cooke photo-visual telescope of 71 inches focus.

As my husband fixed his observing station at the Royal Alfred Observatory, Pamplemousses, and as the Director, Mr. Claxton, gave me every facility, I set up my instruments in the Observatory grounds. The Newbegin telescope was mounted upon the equatorial stand of the photoheliograph which was left vacant, the Mauritius photoheliograph having been dismounted in order that it might be used in connection with the 16-inch cœlostat of the official Greenwich Expedition. The photoheliograph dome stands on the east of the Observatory grounds, and about 150 feet to the west of the dome I set up the Waters equatorial lent to my husband by the Royal Astronomical Society, which I used to carry two little cameras, each with a 1½-inch Dallmeyer Stigmatic lens. About 105 feet further west the camera belonging to the Waters telescope was firmly fixed, pointing directly to the Sun, and by its side the Niblett lens belonging to the British Astronomical Association, a photographic lens 4 inches in diameter, and of 34 inches focus. This was likewise fixed rigidly. Mr. Nevil Maskelyne, F.R.A.S., also lent me his kinematograph, and this was mounted a few feet further south. The management of these instruments during the eclipse was very kindly undertaken by several friends, and I was

further helped by three non-commissioned officers who had volunteered to assist in the eclipse observations. The entire party was arranged as follows:—

Personnel.

Mr. A. Walter: Newbegin photo-visual telescope, 71 inches focus.

Bombadier A. H. Thorne: Recorder to Mr. Walter.

Mrs. Walter Maunder: Dallmeyer Stigmatic lens twin camera, 9 inches focus.

Sergeant J. H. Tyson: Recorder to Mrs. Maunder.

Lance-Corporal A. Balguè: Waters camera, 8 feet equivalent focus.

Mr. G. H. Ireland: Kinematograph. The kinematograph gave no result, the film tearing across before totality was reached.

(Mr. Ireland brought a camera of about 2 feet focus, which was mounted as a stationary camera, and six exposures were made with it by Mr. T. W. Hanning.)

I add here a brief description of the photographs obtained:

1. *The Dallmeyer Stigmatic Twin Camera.*

These lenses are each $1\frac{1}{2}$ inches aperture, 9 inches focus, and give a field nearly 40° in diameter on a plate 16 cm. square. I procured one of these lenses in 1897, on account of its great field, in order to photograph the Milky Way, and it being the only photographic lens I then possessed, I took it to India in 1898. Exposures of 20 seconds made with it upon the corona of that year, recorded the coronal extensions much further from the Sun than they had been photographed before; in one instance to a distance of 13·9 lunar radii from the Sun's centre. My purpose on this occasion was to repeat the Indian exposures of 20 seconds, and also to try the effect of exposures longer still. I therefore gave two exposures with each camera—one of 2 minutes and one of 20 seconds.

No. 1.—From 30 seconds to 150 seconds. Exposure 120 seconds. Sandell Triple-coated plate.

A fairly dense negative. The chromosphere has come up as a very brilliant ring, but the motion of the Moon across the Sun's disc during the very considerable exposure is very apparent. Of course no detail of the inner corona is seen on such a small image, except the large prominence on the east limb of the Sun, but the outer corona is fairly defined, tapering in long rod-like rays which on the east side of the corona reach a distance from the Sun of about five lunar radii, and on the west side of about six.

No. 2.—From 30 seconds to 150 seconds. Exposure 120 seconds. Imperial Special Rapid plate.

This negative is not so dense nor so well defined as No. 1. The

sky glare has come up, and the extensions are not so considerable as in the former case.

No. 3.—From 170 seconds to 190 seconds. Exposure 20 seconds. Sandell Triple-coated plate.

The image of the corona is fairly dense, but the sky glare has not come up so much as in the previous cases, and it shows as great extension as No. 1.

No. 4.—From 170 seconds to 190 seconds. Exposure 20 seconds. Imperial Special Rapid plate.

This is a weak image, and has no points to recommend it.

(Nos. 3 and 4 have a double image on them, due probably to the cameras not having settled down after the plate-carriers were changed.)

2. *The Niblett Lens.*

This lens is of 4 inches aperture and 34 inches focus, fitted with a revolving drum carrying 5-inch by 4-inch plates.

No. 1.—Exposed at second contact. Exposure about $\frac{1}{4}$ second. Imperial Fine Grain plate.

This photograph was taken at second contact, and several "beads" of sunlight are seen. Nevertheless, not only is there a great deal of detail to be seen in the middle corona, but on the west side a coronal ray can be traced to two lunar radii, and on the east side to a somewhat greater distance. The image is a fairly dense one. The image is not large enough, nor was the exposure sufficiently short to show any detail in the prominences or chromosphere, but the polar rays and the "combing out" of the equatorial wings are well seen.

No. 2.—Exposed at 40 seconds. Exposure about $\frac{1}{4}$ second. Imperial Ordinary plate.

A fairly dense image, showing the polar rays and middle corona well.

No. 3.—Exposed at 80 seconds. Exposure about $\frac{1}{4}$ second. Imperial Special Rapid plate.

The image is not so dense as in the previous cases, but the coronal rays can be traced to a greater distance, as can also the polar rays.

No. 4.—Exposed at 120 seconds. Exposure about $\frac{1}{4}$ second. Imperial Special Rapid plate.

A weak faint image, under-developed. No detail shown.

No. 5.—Exposed at 160 seconds. Exposure about $\frac{1}{4}$ second Imperial Ordinary plate.

Under developed, only the chromospheric ring seen.

No. 6.—Exposed at 200 seconds. Exposure about $\frac{1}{4}$ second. Imperial Fine Grain plate.

A good image, not very dense, showing the middle corona and polar rays well.

3. *The Newbegin Telescope.*

This lens is a Cooke photo-visual objective of $4\frac{1}{4}$ inches aperture and 71 inches focus. The photographs were taken on quarter plates. They form an exceedingly fine series of fourteen, taken on different makes of plate and with differing exposures. They bear magnification well up to the limit we have yet tried, namely, to one giving 4 inches to the Sun's diameter. Every photograph in this series was successful.

No. 1.—Exposed 7 seconds after commencement of totality. Exposure instantaneous. Plate, Lumière Orthochromatic, Series A.

This is a not very dense negative, and shows the prominences on the east side of the Sun, and the very complicated structure of the corona surrounding them. From the large prominence on the Sun's east equatorial limb two very marked and irregular black rifts or streaks cross the coronal wing and seem to broaden as they get further away from the Sun. A similar single streak leaves the Sun's surface to the south of the large prominence in the south-east.

No. 2.—Exposed at 21 seconds after commencement of totality. Exposure, 2 seconds. Plate, Imperial Fine Grain Ordinary.

A denser negative than No. 1, showing great extension of the polar rays. In the northern polar rays is seen a forked dark marking cutting the rays obliquely.

No. 3.—Exposed at 32 seconds after the commencement of totality. Exposure 4 seconds. Plate, Imperial Fine Grain Ordinary.

The dark marking in the north polar rays is clearly seen. There is a greater extension on the north-western side of the corona than in the two previous photographs.

No. 4.—Exposed at 45 seconds after commencement of totality. Exposure 6 seconds. Plate, Imperial Fine Grain Ordinary.

The corona is distinctly larger than on the previous photographs, and the dark marking cutting the north polar rays is very clearly seen.

No. 5.—Exposed 1 minute after commencement of totality. Exposure 8 seconds. Plate, Imperial Fine Grain Ordinary.

A negative very similar to No. 4.

No. 6.—Exposed at 77 seconds after commencement of totality. Exposure 10 seconds. Plate, Imperial Fine Grain Ordinary.

No. 7.—Exposed at 94 seconds after totality. Exposure 6 seconds. Plate, Imperial Ordinary.

This negative is perhaps not so well defined as the others.

No. 8.—Exposed at 107 seconds after totality. Exposure 6 seconds. Plate, Imperial Ordinary.

This negative is not very dense, but the corona is very large, and it shows a greater extension of the coronal rays than any of the previous ones.

No. 9.—Exposed at 126 seconds after totality. Exposure 10 seconds. Plate, Imperial Fine Grain Ordinary.

No. 10.—Exposed at 144 seconds after totality. Exposure 8 seconds. Plate, Imperial Fine Grain Ordinary.

No. 11.—Exposed at 162 seconds after totality. Exposure 6 seconds. Plate, Imperial Fine Grain Ordinary.

On this negative it is very clearly seen that the bulbous curves at the base of the great north-east wing are laid over and across other coronal curves in the background.

No. 12.—Exposed at 176 seconds after totality. Exposure 4 seconds. Plate, Imperial Fine Grain Ordinary.

This photograph shows perhaps best the corona in the south-west region. Here there seem to be a number of synclinal groups, which give the impression of not being all in the plane of the photograph, as usually appears to be the case in coronal negatives, but in different planes.

No. 13.—Exposed at 191 seconds after totality. Exposure 2 seconds. Plate, Imperial Fine Grain Ordinary.

The corona is here very restricted. In the south-west region the exposure does not seem to have been sufficient to bring up all the synclinal groups, and in consequence the south polar rays have the appearance of encroaching on this side.

No. 14.—Exposed at 202 seconds after the commencement of totality. Exposure instantaneous. Plate, Lumière Orthochromatic, Series A.

This negative is fainter then any of the others, but shows well the detail and prominence in the south-west region of the corona.

4. *The Waters Camera.*

This is a Dallmeyer portrait combination of 2 inches aperture and 8 feet equivalent focus, a Dallmeyer telephoto lens being used as a negative enlarger. The photographs were taken on half plates. The enlargement is rather too great for detail of any importance to be shown, and there is therefore no need to describe them in detail. Exposures of about a quarter of a second were given in all cases.

No. 1.—Exposed at second contact. Plate, Imperial Special Rapid.
No. 2.—Exposed at 40 seconds. Plate, Imperial Special Rapid.
No. 3.—Exposed at 80 seconds. Plate, Imperial Flashlight.
No. 4.—Exposed at 120 seconds. Plate, Imperial Flashlight.
No. 5.—Exposed at 160 seconds. Plate, Imperial Flashlight.
No. 6.—Exposed at 200 seconds. Plate, Imperial Special Rapid.

5. *The Pinhole Camera.*

This was a camera with pinhole aperture of $\frac{1}{32}$ of an inch, and the plate was placed at a distance of 30 inches. The plate was exposed immediately before second contact, and closed immediately after third. A small arc of sunlight is thus seen both on the east and west limbs of the Moon. A coronal ring, about 4 minutes in greatest height, is seen connecting these arcs. The little photograph has of course no scientific value, but as being the only instance of a photograph of the corona taken with a pinhole, it may rank as a curiosity. The ratio of aperture to focal length was as 1 to 960, and the exposure given to the plate would correspond to one of $\frac{1}{15}$th of a second, as given with the Newbegin. The plate used was an Imperial Special Rapid.

6. *Photographs of the Landscape.*

At my request M. Alexander Rambert, a professional photographer of Mauritius, took a series of photographs of the landscape during the coming on and passing off of the shadow. The same exposure was given in every instance, the plates were all from the same batch, and they were developed at one and the same time, in the same bath and for the same length of time. The exposures were made at regular intervals of 5 minutes, the first being taken $27\frac{1}{2}$ minutes before mid-totality, the last $27\frac{1}{2}$ minutes after. A comparison of the plates taken before totality with those taken at corresponding times after, shows a slight but appreciable increase in density in the later plates as compared with the earlier, but perhaps not more than would be accounted for by the increase in altitude of the Sun.

MONTHLY NOTICES

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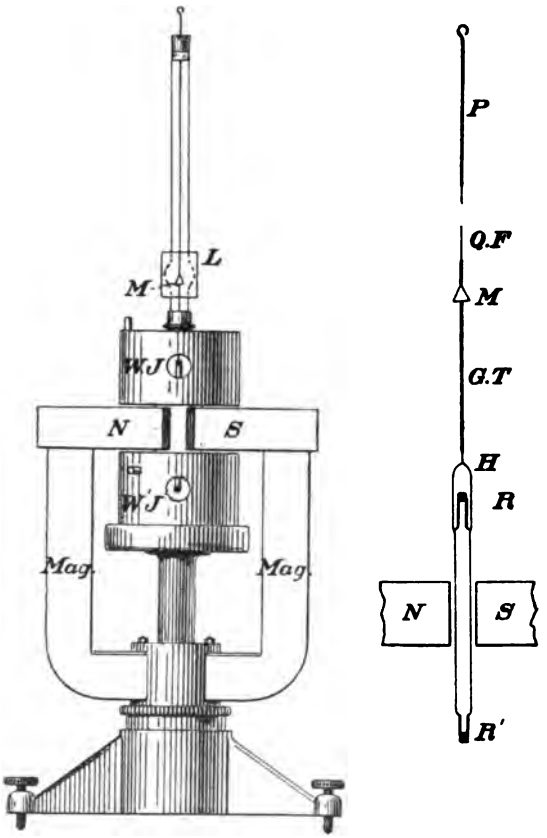
"The Effective Temperature of the Sun." By W. E. WILSON, D.Sc., F.R.S. Received December 5,—Read December 12, 1901.

In March, 1894, Dr. G.Johnstone Stoney communicated to the Society a memoir by myself and Mr. P. L. Gray, entitled "Experimental Investigations on the Effective Temperature of the Sun," which was published in the 'Phil. Trans.,' A, vol. 185 (1894). In these investigations the method we adopted was as follows:—A beam of sunlight was sent horizontally into the laboratory by means of a Stoney single-mirror heliostat. The mirror was an optical plane of unsilvered glass, and the beam was directed into one aperture (A) of a differential Boys' radio-micrometer. The other aperture (B) received the radiation from a strip of platinum, which could be raised to any desired temperature by an electric current supplied by a battery of accumulators. The temperature of this strip was at any moment determined by its linear expansion, the instrument being previously calibrated by melting on it minute fragments of AgCl and of pure gold, as in Joly's meldometer. In front of the aperture (B) of the radio-micrometer was placed a stop with a circular hole of 5·57 mm., and the distance of this hole from the receiving surface of the thermo-couple was 60·2 mm. This gave for the angle subtended by a diameter of the aperture at the receiving surface 5°·301. Knowing then (i) the ratio which the angular diameter of this circular aperture bears to that of the sun, (ii) the temperature of the platinum strip at the moment that the radio-micrometer is balanced, (iii) the amount of the sun's radiation lost by reflection from the heliostat mirror and also by absorption in the earth's atmosphere, it is possible on any assumption with regard to the law connecting radiation with temperature, to determine the effective temperature of the sun. A series of very accordant observations were made in this way, the mean of which gave 6200° C. as the effective solar temperature.

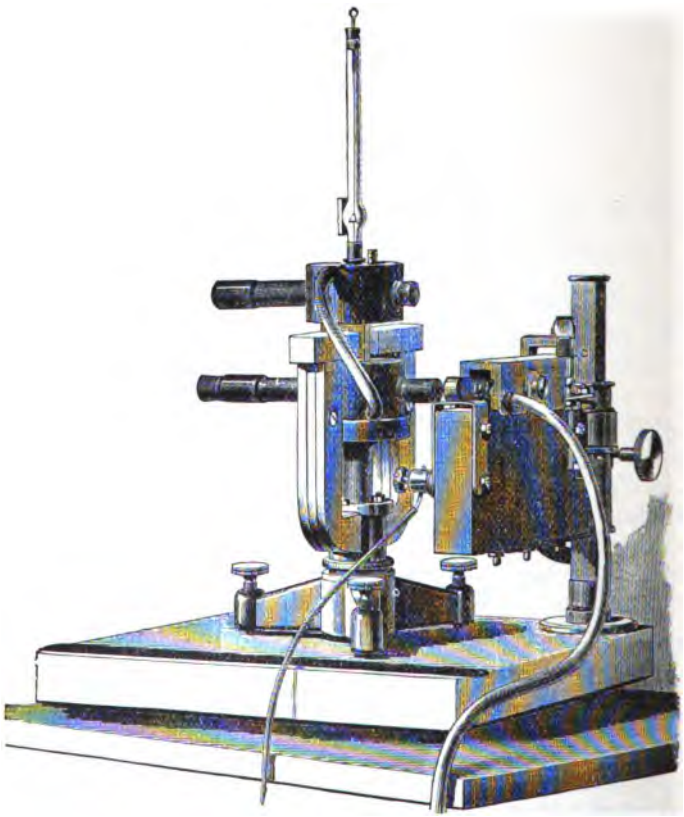
For the details of the apparatus and the complete method of reduction of the observations, the original memoir in the ' Phil. Trans.' may be referred to.



In order to protect the incandescent strip from draughts of air it was covered with a water-jacket of gilded brass. This was provided with a circular hole in one of its longer sides, through which its radiation could reach the aperture of the radio-micrometer. The internal walls of this water-jacket being highly polished, it has occurred to me, since the publication of the memoir referred to, that possibly some of the radiation from distant parts of the platinum strip may have been reflected backwards and forwards from the polished walls and the strip itself, ultimately escaping through the aperture and reaching the radio-micrometer, thus increasing the amount of radiation which should have reached it directly from the strip alone.

In order to test this surmise I first took a number of readings at known temperatures with the walls of the water-jacket polished as

before. I next smoked the surface of the walls well, and found that the amount of radiation coming from the aperture was then sensibly reduced. It is also possible that changes in the condition of the surface of the platinum strip may effect its emissivity, and in fact it is very doubtful whether it is possible to determine with any degree of accuracy what the emissivity of bright platinum is, relatively to lamp



black. In the original memoir we took Rosetti's estimate of 35 per cent. as the most probable value for this quantity, but as our former estimate of the solar temperature depends greatly on this factor, to which so much uncertainty attaches, I thought it would be a distinct advance to abolish entirely the platinum strip as a source of radiation, and to substitute in its place a uniformly heated enclosure which would radiate as an absolutely "black body."

In 1895 Mr. Lanchester pointed out to me that such an enclosure would be a theoretically perfect radiator; while Lummer, Paschen and others have shown that the law connecting temperature and

radiation from such an enclosure confirms in a remarkable manner Stefan's law of radiation, viz., $R = aT^4$.* Since therefore the results of several independent investigations corroborate this law, I have felt justified in applying it to the results of my observations.

On consideration it seemed that the most convenient form of radiator would be a long tube closed at one end, and uniformly heated in a gas furnace. Accordingly a porcelain tube, 2 feet in length and 1 inch internal diameter, was fitted into a Fletcher gas-tube furnace. This was afterwards changed for an iron tube, which was employed in the observations on September 30th, given below.

A plug of asbestos was inserted in the tube at about 10 inches from the end farthest from the radio-micrometer, and resting against this plug was the end of a Callendar platinum-resistance thermometer. This was connected with one of Professor Callendar's electric recorders, so that during an experiment the temperature of the tube was registered continuously on the paper wrapped round the drum of the instrument. In front of the open end of the tube, and between it and the radio-micrometer, was placed a large brass water-screen, through which a copious supply of water passed. In front of the aperture (B) of the radio-micrometer this screen was provided with a rectangular aperture. One side of this aperture was formed by a slide moved by a micrometer screw reading to 0·01 mm. By this means the area of this aperture at any time could be measured with precision. Its fixed sides were 5 mm. apart, and as the movable side had a range of 5 mm., the maximum area of the aperture was 25 sq. mm. The distance (d) of this aperture from the surface of the thermo couple was 66·3 mm.

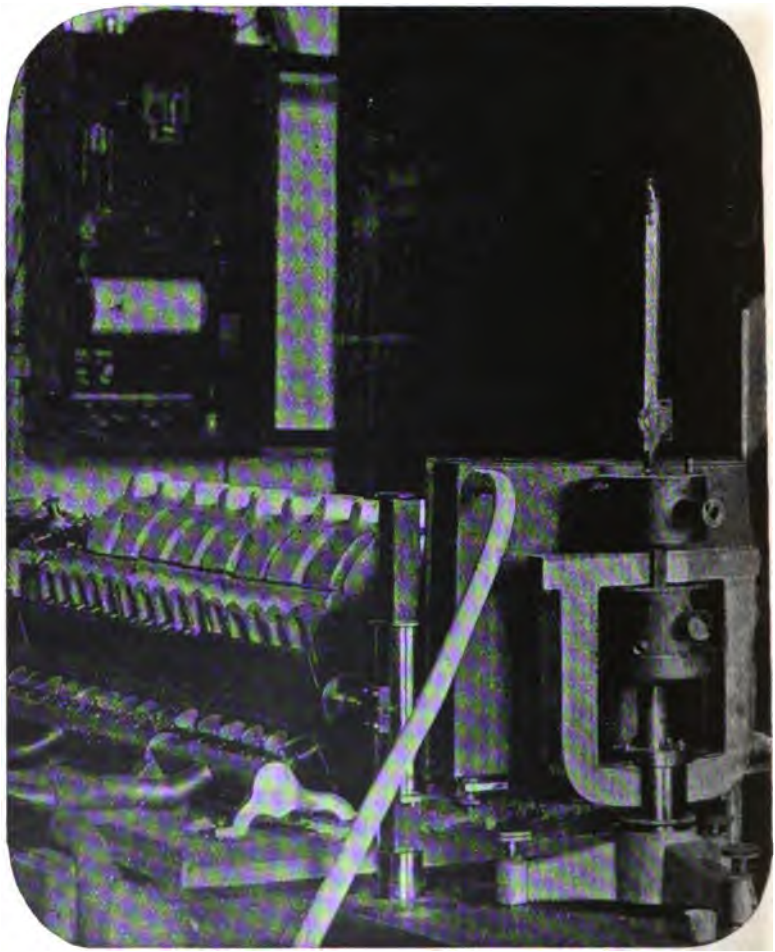
To make an observation the tube was heated to as high a temperature as the furnace was capable of, and when a steady temperature had been obtained, the amount of radiant heat coming from the interior of the hot tube and passing into the aperture (B) of the radio-micrometer was adjusted by the micrometer screw until a balance was obtained with the radiation coming from the Sun through the aperture (A).

If ρ is the angular semi-diameter of the sun, its radiation outside of our atmosphere is $K.\pi \sin^2 \rho$, where K is a constant depending on the sun's temperature.

Again, if α be the height of the slit through which the radiation from the hot tube reaches the radio-micrometer, and β its width, the radiation may with sufficient accuracy be expressed by $K\alpha\beta/d^2$. Assuming Stefan's law, the radiation of the sun outside our atmosphere is $a\theta^4\pi \sin^2 \rho$, θ being the effective temperature of the sun.

* Stefan, 'Sitzber. d. k. Akad. zu Wien,' vol. 79, 1879 (Abth. 2), p. 391; Boltzmann, 'Wied. Ann.,' vol. 22, 1884; M. Planck, 'Drude Ann.,' vol. 1, No. 1, 1900; Paschen, 'Wied. Ann.,' vols. 58, 60, 1896, 1897; Lummer and Pringsheim, 'Wied. Ann.,' vol. 63, 395, 1897.

The percentage transmitted is p, therefore the radiation before reflection from the heliostat is $\frac{ap\theta^4}{100} \pi \sin^2 \rho$.



At reflection q per cent. is transmitted, therefore the radiation received by the radio-micrometer is

$$a \cdot \frac{pq\theta^4}{(100)^2} \cdot \pi \sin^2 \rho \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1).$$

Also the radiation received from the hot tube is

$$a'(T^4 - T_0^4) \cdot \frac{\alpha\beta}{d^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2).$$

We need not inquire what is the absorptive power of the thermo-junction, provided that we are justified in assuming that lamp-blacked surfaces absorb the radiation from the hot tube as freely as that from the sun, or that the constants in these expressions (1) and (2) for the radiation may be taken to be equal.

On balancing, these expressions must be equal, and therefore

$$\frac{pq\theta^4}{(100)^2} \cdot \pi \sin^2\rho = (T^4 - T_0^4)\frac{\alpha\beta}{d^2}$$

$$= T^4\left(1 - \left(\frac{T_0}{T}\right)^4\right)\frac{\alpha\beta}{d^2} \quad \ldots\ldots\ldots\ldots (3).$$

But $\left(\frac{T_0}{T}\right)^4$ may be neglected, hence we have finally

$$\theta^4 = \frac{\alpha}{\pi d^2}\ \frac{\beta}{\sin^2\rho}\ \frac{100}{p}\ \frac{100}{q}\ T^4$$

or
$$\theta = \sqrt[4]{\frac{10000\,\alpha}{\pi d^2}} \cdot \sqrt[4]{\frac{\beta}{pq\sin^2\rho}} \cdot T$$

$$= \frac{0{\cdot}13806}{\sqrt{\sin\rho}} \cdot \sqrt[4]{\frac{\beta}{pq}} \cdot T.$$

The mean value of $\frac{0{\cdot}13806}{\sqrt{\sin\rho}}$ is [1·30413].

Therefore
$$\theta = 1{\cdot}30413 \cdot \sqrt[4]{\frac{\beta}{pq}} \cdot T \quad \ldots\ldots\ldots\ldots (4).$$

After a series of observations had been made, the furnace and tube were raised so that the radiation of the latter then passed into the aperture (A), on which the sunlight had previously fallen, while the beam of sunlight was now directed so as to be upon (B), and in this position a second series of observations was taken. The geometrical mean of the result of the two groups gives the Effective Temperature of the Sun, the effect of any difference in the sensitiveness of the thermo-junctions disappearing in the geometrical mean.

Observations were made in the manner described above on August 19th and September 30th, 1901, and reduced by means of equation (4), as exhibited in the following tables. In these the successive columns contain (1) the local mean time, (2) the value of β as read on the micrometer head, (3) the absolute temperature of the tube in the furnace, (4) the sun's altitude, (5) the percentage of the sun's radiation transmitted through the earth's atmosphere, (6) the angle of incidence on the heliostat mirror, (7) the percentage reflected from the surface of the mirror, (8) the corresponding value of θ deduced from equation (4). Of these (5) and (6) and (7) were determined as in Wilson and Gray's memoir referred to above.

Note, $\alpha = 7$ mm.

Local time.	Balance. Reading.	Balance. Temp. absolute.	⊙ Altitude.	Per cent. trans.	Angle of incidence.	Per cent. reflected.	⊙ Temp. absolute.	Date, August 19, 1901. Blue sky.
h. m.			° ′		°		°	
11 0	1·68	1099	47 18	66	62	9	5586	First Position (B).
11 3	1·69	1098	47 36	66	62	9	5589	,,
11 7	1·70	1098	47 44	66	62	9	5598	,,
11 19	1·60	1100	48 24	66	62	9	5503	,,
11 22	1·55	1100	48 25	66	62	9	5459	,,
11 28	1·62	1101	48 41	66	63	11	5161	,,
11 30	1·70	1101	48 42	66	64	12	5223	,,
11 36	1·75	1101	48 50	66	64	12	5262	,,
11 36	1·77	1101	48 54	67	64	12	5278	,,
11 38	1·80	1101	49 0	67	64	12	5286	,,
						Mean	5394	,,
12 48	3·99	1119	48 20	67	68	15	6192	Reversed Position (A).
12 51	4·00	1119	48 13	67	68	15	6184	,,
12 53	3·98	1119	48 6	67	68	15	6186	,,
12 56	3·96	1119	48 0	67	68	15	6190	,,
12 58	3·98	1119	47 49	66	68	15	6210	,,
1 3	3·94	1119	47 39	66	68	15	6193	,,
1 5	3·93	1119	47 36	66	68	15	6190	,,
1 7	3·93	1119	47 24	66	68	15	6190	,,
1 9	3·92	1119	47 18	66	68	15	6186	,,
1 11	3·96	1119	47 18	66	68	15	6202	,,
						Mean	6192	,,

Geometrical mean of A and B = $\sqrt{5394 \times 6192} = 5779°$.

Note, $\alpha = 5$ mm.

Local time.	Balance. Reading.	Balance. Temp. absolute.	⊙ Altitude.	Per cent. trans.	Angle of incidence.	Per cent. reflective.	⊙ Temp. absolute.	Date, Sept. 30, 1901. Weather, slight haze.
h. m.		°	° ′	°			°	
10 45	2·05	1107	31 30	59	64	11	5318	First Position (B).
10 52	2·16	1112	32 0	59	64	11	5379	,,
10 55	2·17	1113	32 0	60	64	11	5364	,,
11 25	2·55	1124	33 0	61	66	12	5146	,,
11 38	2·42	1124	33 0	61	67	13	5320	,,
						Mean.....	5365	
11 51	5·20	1127	33 0	61	68	14	6302	Reversed Position (A).
11 55	6·05	1127	33 0	61	68	14	6585	,,
12 0	6·02	1126	33 0	61	68	14	6570	,,
12 8	5·39	1127	33 0	61	69	15	6290	,,
12 18	5·67	1128	32 30	60	70	17	6201	,,
12 25	5·18	1126	32 30	60	70	17	6053	,,
12 32	5·25	1127	32 15	60	71	18	5992	,,
12 36	5·18	1126	32 0	60	71	18	5968	,,
12 50	5·55	1122	32 0	60	71	18	6050	,,
12 58	5·25	1122	31 30	59	71	18	5992	,,
						Mean.....	6201	

Geometrical mean of A and B = $\sqrt{5365 \times 6201} = 5768°$.

In the above tables Rosetti's determination of the amount of the terrestrial atmospheric absorption has been used. It may be well, however, to give the results obtained by using other estimates of this quantity. Taking Langley's transmission coefficient when the sun is in the zenith as 59 per cent., compared to Rosetti's 71 per cent., the temperature would be multiplied by $\sqrt[4]{(71/59)}$ and thus become $5773 \times 1{\cdot}054$, which is 6085° absolute. And, as in the previous memoir, to make the case general, if any later investigation shows the zenith transmission coefficient to be x per cent., the effective absolute temperature becomes

$$5773^\circ \times \sqrt[4]{(71/x)}.$$

It may also be of interest to see what effect is produced if absorption in the atmosphere of the sun itself is taken into account. First, considering the falling off in radiation from the central to the peripheral parts of the sun's disc, we may deduce that, if the absorption were everywhere equal to that at the centre, the radiation would be multiplied by 4/3 and the temperature would become

$$5773^\circ \times \sqrt[4]{(4/3)} = 5773 \times 1{\cdot}074 = 6201^\circ.$$

Secondly, assuming Wilson and Rambaut's* result for the total loss due to absorption in the solar atmosphere as equal to one-third, our estimate of the temperature would have to be multiplied by $\sqrt[4]{(3/2)}$, and we get finally

$$6201^\circ \times \sqrt[4]{(3/2)} = 6201^\circ \times 1{\cdot}107 = 6863^\circ \text{ absolute} = 6590^\circ \text{ C.}$$

I wish to express my thanks to Dr. Rambaut for some valuable suggestions during the progress of the work.

"The Chemical Origins of the Lines in Nova Persei." By Sir Norman Lockyer, K.C.B., F.R.S. Received December 23, 1901,—Read January 30, 1902.

In the first two papers† which I communicated to the Royal Society on the observations of Nova Persei at Kensington, a general description of the spectrum in its earliest stages was given, and also a statement as to the probable origins of some of the strongest lines, depending upon a comparison of the Nova Spectrum with those of α Cygni, α Canis Majoris, γ Orionis, &c.

A table showing the results of the detailed reduction and discussion

* "The Absorption of Heat in the Solar Atmosphere," 'Proceedings Royal Irish Academy,' 1892, vol. 2, No. 2.

† 'Roy. Soc. Proc.,' vol. 68, p. 119 and p. 142.

Comparison Table of Bright Lines in the Spectra of Nova Persei and Nova Aurigæ with α Cygni Lines, Chromospheric Lines, and the Enhanced Lines of some of the Metals

Nova Persei (Kensington).		Nova Aurigæ.		α Cygni.	Chromosphere (1898 Eclipse).	Enhanced lines.		Remarks.
λ of middle of line.	Description of line.	Campbell.	Vogel.			λ.	Substance.	
3836	Very broad, weak	—	3835	—	3835·6	—	—	Hη.
3889	Very broad. ? Narrow reversal in centre	—	3889	3889·1	3889·1	—	—	Hζ.
3934	Broad, rather weak. Fine narrow reversal in centre	—	3934	3933·8	3933·83	3933·83	*p*Ca	K(Ca).
3969	Very broad and fairly strong; shows fine narrow reversal in position of H(Ca) and possibly another weaker one in position of Hε	—	3969	3968·6 3970·2	3968·63 3970·25	3968·63	*p*Ca	H(Ca) + Hε.
3982 4003 4019 4029 4067	All these are very weak diffuse lines which can just be seen with the unaided eye, but which will not bear any magnification, and their wavelengths can only be roughly determined	— — — —	— — — 4067	4002·7 4028·5 4067·3	— 4028·5 4067·3	4002·77 4028·50 4067·30	*p*Fe *p*Ti *p*Ni	Strongest enhanced line of Ni.
		4082	—	4077·9	4077·9	4077·88	*p*Sr	
4102	Broad and strong	4095 4102 4108	4102	4101·8	4101·9	—	—	Hδ.

Comparison Table—*continued.*

Nova Persei (Kensington).		Nova Aurigæ.		α Cygni.	Chromosphere (1898 Eclipse).	Enhanced lines.		Remarks.
λ of middle of line.	Description of line.	Campbell.	Vogel.			λ.	Substance.	
4128	Very broad and merging into Hδ	4126	4125	4128·1 4131·1	— —	4128·1 4131·1	*p*Si *p*Si	
		4166	4158	4163·8	4163·8	4163·82	*p*Ti	
4175	Broad and fairly strong.....	4180 4209	4176	4173·5 4179·0	4173·5 4179·0	4173·52 4178·95	*p*Fe *p*Fe	Mean λ of enhanced double = 4176·23.
4232	Broad, but not very strong	4227 4236	4230	4233·3	4233·3	4233·25	*p*Fe	
4247	Comparatively narrow, but merging into the broader 4232 line, slightly stronger than the latter	4246	—	4247·2	4247·0	4247·00	*p*Sc	Strongest spark line of Sc.
4262	Narrow, but fairly strong	4267	4262	4262·2	—	4262·15	*p*Cr	
			4288	4290·4	4290·2	4290·38	*p*Ti	
4300	Broad line, fairly strong.....	4296	—	4296·7 4300·2 4303·3	4296·7 4300·2 4303·0	4296·65 4300·21 4303·34	*p*Fe *p*Ti *p*Fe	Mean λ of enhanced Fe double = 4300.
4314	Comparatively narrow, merging into 4300	4316	4315	4315·1	4314·0 4315·1	4315·14	*p*Ti	Possibly due to Sc 4314·25, one of the strongest spark lines.
4341	Broad and very strong. Doubtful reversal in centre	4331·3 4340·6 4347·8	4341	4340·7	4340·7	—	—	Hγ.
		4355	—	—	4355			
		4375	—	4374·9	4374·9	4374·90	*p*Ti	
		4385	4383	4385·5	4385·5	4385·55	*p*Fe	

4392	Fairly broad, rather weak.							
4411	Broad and moderately strong ...	—	—	4411·2	4411·2	4411·20	*p*Ti	
		4419	4417	4417·0 4417·9	4417·9	4417·88	*p*Ti	
4425	Weak and rather narrow.							
4434	— —	4436	4435	4434·4	4435·5			
4444	Fairly broad, but weak	4445	4445	4444·0	4144·0	4443·98	*p*Ti	
4454	Rather narrow, weak.							
4470	„ „ and weak	4471	4473	4468·7	4468·7	4468·66	*p*Ti	
4481	„ „ fairly strong.....	4481	4480	4481 3		4481·30	*p*Mg	Strongest enhanced line of Mg.
4493	„ „ „ „	4490	4495	4489·0 4491·6	4489·3 4491·6	4489·35 4491·57	*p*Fe *p*Fe	
4509	„ „ „ „	4502	4507	4501·5	4501·5	4501·45	*p*Ti	
				4508·5	4508·5	4508·46	*p*Fe	
				4515·5	4515·5	4515·51	*p*Fe	
4519	„ „ „ „	to	4520	4520·4	4520·4	4520·40	*p*Fe	
				4522·7	4522·7	4522·69	*p*Fe	
4535	„ „ weak.....	4534	4530	4534·1	4534·1	4534·14	*p*Ti	
4548	„ „ moderately strong	4549	—	4549·8	4549·7	4549·64 4549·81	*p*Fe *p*Ti	
		4554	4557	4556·1	4556·1	4556 10	*p*Fe	
		4559		4558·8	4558·8	4558·83	*p*Cr	
		4564	—	4563·9	4563·9	4563·94	*p*Ti	
4568	„ „ „ „	4570	—	4572·2	4572·2	4572·16	*p*Ti	
		4576	—	4576·5	4576·5	4576·51	*p*Fe	
4583	„ „ but fairly strong.	4586	4583	4584·0	4584·0	4584·02	*p*Fe	
4628	Broad and fairly strong	4630	4628	4629·6	4629·5	4629·50	*p*Fe	
4670	„ rather weak	4669						
4705	„ weak	4707	—	—	4707·8			
		4737	—	—	4737·0			
		4774						
*4822	Fairly broad, weak	—	—	4824·3	4824·3	4824·33	*p*Cr	Strongest enhanced line of Cr.
4862	Very broad and strong.....	4851·2 4861·6 4869·9	4862	4861·5	—	—	—	Hβ.

Comparison Table—*continued.*

Nova Persei (Kensington).		Nova Aurigæ.		α Cygni.	Chromosphere (1898 Eclipse).	Enhanced lines.		Remarks.
λ of middle of line.	Description of line.	Campbell.	Vogel.			λ.	Substance.	
4924	Broad and strong.....	4913 4923 4929 4969	4923 4925	4924·1	4924·1	4924·11	*p*Fe	
5019	„ „	5007 5018 5095 5142	5016	5018·6	5018·6	5018·63	*p*Fe	
5169	Broad and very strong	5159 5169 5176 5200	5167	5169·1	5169·1	5169·07 5169·22	*p*Fe	Certainly not the *b*-group of magnesium.
*5224	Narrow and weak.	5234	523	—	5234·8			
*5273	„ „	5276 5285	528	—	5275·1 to 5276·2	5276·17	*p*Fe	
5316	Moderately broad and strong....	5318 5329 5379	5317	5316·8	5316·8	5316·79	*p*Fe	
*5420	Weak and rather narrow.	5454						
*5475	Weak and narrow.							
*5530	Fairly strong and broad.....	5535	—	—	5527·6	5527·08	*p*Sc	By far the strongest spark line of Sc in the visual region.

*5575	„	„	„	.....	5575 5584 5630	}					
*5686	„	„	„	.....	5685 5761 5841 5885						
*5893	„	„	„	.....	5896	5686†	—	{5890·2 5896·2}	—	—	D(Na).

† As given by Vogel (probably 5886).

Note.—The lines marked * cannot be seen in the photographs taken with the 6-inch prismatic camera, and their positions have been reduced from the spectrum photographed with the 30-inch reflector with a two-prism slit spectroscope.

of the bright lines in the best spectrum typical of the Nova in this early stage (that obtained with the 6-inch objective prism on February 25, when the star was nearly as bright as Capella), was undertaken later for inclusion in a general summary of the observations in course of preparation.

As various conclusions as to the chemical origin of some of the Nova lines have recently been published which differ widely from those arrived at from a careful study of the Kensington photographs, I think it desirable to publish the above-mentioned table at once. A detailed statement of the evidence on which these conclusions as to origin are based, will follow in the general summary before referred to.

That many of the stronger lines in the early spectra of Nova Aurigæ were chromospheric, has been pointed out by several observers, and all agree that there is little difference in the general aspect of the spectrum of Nova Aurigæ and that of Nova Persei at a corresponding stage of development. In confirmation of this it may be said that by means of direct comparison of the various Kensington photographs, the identity of most of the strong bright Nova bands with lines of α Cygni and the chromosphere—already known to be due to enhanced lines of certain metals—has been established.

With regard to the stellar relations of the Nova, I may state that in my note of February 28,* the agreement in position of its lines with those of α Cygni was pointed out. Later, Mr. McClean† confirmed this, and further stated that the bright lines of η Argus corresponded with the dark lines of the Nova; while later still, Sir David Gill‡ has shown the similarity between the spectra of η Argus and Nova Aurigæ. Hence we are led to the conclusion that the temperatures reached in the outbursts of both these Novæ were not greatly different from those of the stars named, and that in η Argus there are constant conditions which are similar to those temporary conditions which produce the appearance of Novæ.

In the table the lines of Nova Persei are compared with those recorded by Campbell§ and Vogel‖ in Nova Aurigæ.

The probably corresponding lines of α Cygni, chromospheric lines, and enhanced lines, are also given in separate columns.

The reduction to wave-lengths and discussion of the lines in relation to those of other celestial and terrestrial spectra, has been undertaken by Mr. F. E. Baxandall, to whom my best thanks are due.

* 'Roy. Soc. Proc.,' vol. 68, p. 121.
† 'M.N., R.A.S.,' vol. 61, p. 387.
‡ 'Roy. Soc. Proc.,' vol. 68, p. 457.
§ 'Ast. and Ast. Phys.,' vol. 11, p. 808.
‖ 'Ast. and Ast. Phys.,' vol. 12, p. 912.

"On some Phenomena which suggest a Short Period of Solar and Meteorological Changes." By Sir NORMAN LOCKYER, K.C.B., F.R.S., and WILLIAM J. S. LOCKYER, M.A., Ph.D., F.R.A.S. Received June 14,—Read June 19, 1902.

In continuation of the inquiries referred to in a former paper on Indian rainfall and solar activity,* attention has more recently been devoted to an examination of the variations of pressure over the Indian and other areas.

1. It is well known that in India during the summer months (April to September) and during the winter months (October to March) low and high pressures respectively prevail. In the case of the latter, the pressure is found to exhibit very remarkable and definite variations, and is in excess, every $3\frac{1}{2}$ years, on the average, while at these times of excess of high pressure the low pressure during the other 6 months of the year is deficient; so that every $3\frac{1}{2}$ years or so the high pressure becomes higher and the low pressure is not so low as usual.

2. Further, this short-period variation, which appears in the mean variation of pressure over the whole of India, is as well defined in the mean values for individual stations, such as Bombay (fig. 1, Curve F), Calcutta, Madras, Nagpur, &c.

3. The view that the variation of pressure in question over India and its neighbourhood is not due to local causes, but is produced by some external or extra-terrestrial action, is considerably strengthened by an examination of the pressure-curve of a very distant station, such as Cordoba. Dealing with the pressure of Cordoba during the high-pressure months, April to September, the curve (fig. 2, Curves F and E), representing the variation from the mean from year to year, is exactly the *inverse* of the curve representing the Bombay and other Indian pressures for the same months over the same period of time. The cause, therefore, which raises the mean value for the low-pressure months over the Indian area would appear to lower the mean value of high-pressure months at Cordoba simultaneously. In fact, we have a see-saw.

* 'Roy. Soc. Proc.,' vol. 67, p. 409.

4. Further investigation shows that not only do the pressures of practically the whole Indian area exhibit variations from year to year, which present very similar features, but that this is the case with

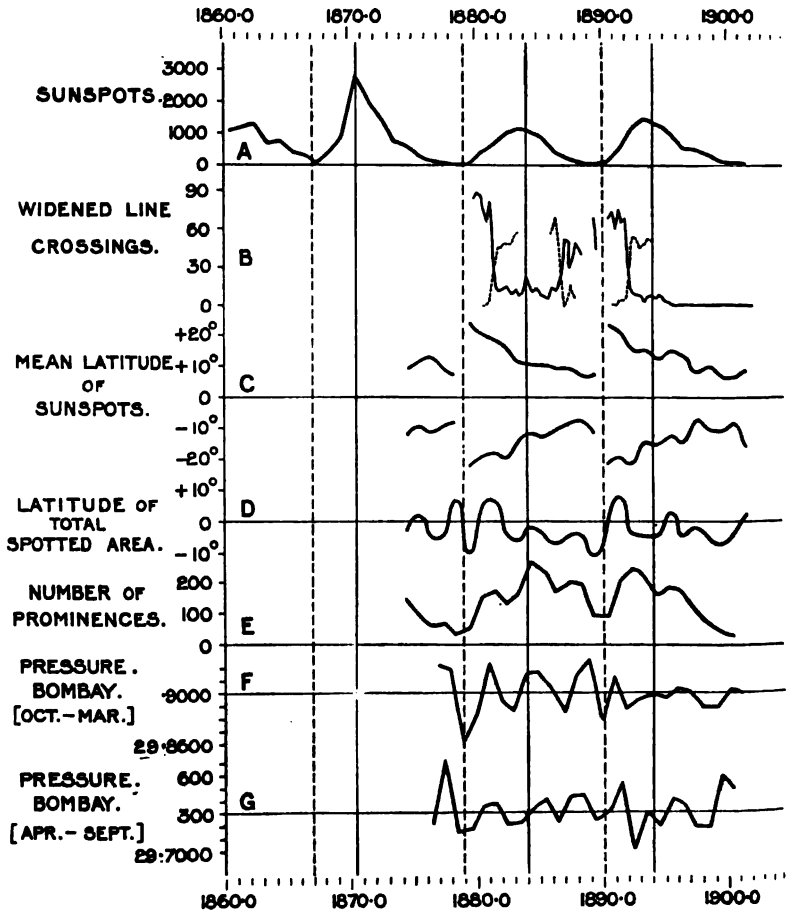


FIG. 1.

other large areas. Thus, for instance, it is found that the yearly mean pressures for Brussels, Bremen, Oxford, Valencia, and Aberdeen (the only pressures that have been at present examined) are all remarkably similar in their variations from year to year, and it might almost be said that one curve, representing the variations from the normal, would approximately define the pressures at all these places.

The probable extra-terrestrial origin of these short-period variations led to a detailed examination of the records of the phenomena con

nected with solar spots and prominences, with a view of seeing whether similar variations, indicating changes in the solar activity, could be detected.

5. A preliminary reduction of the Italian observations of prominences observed on the sun's limb since 1871 was first undertaken.

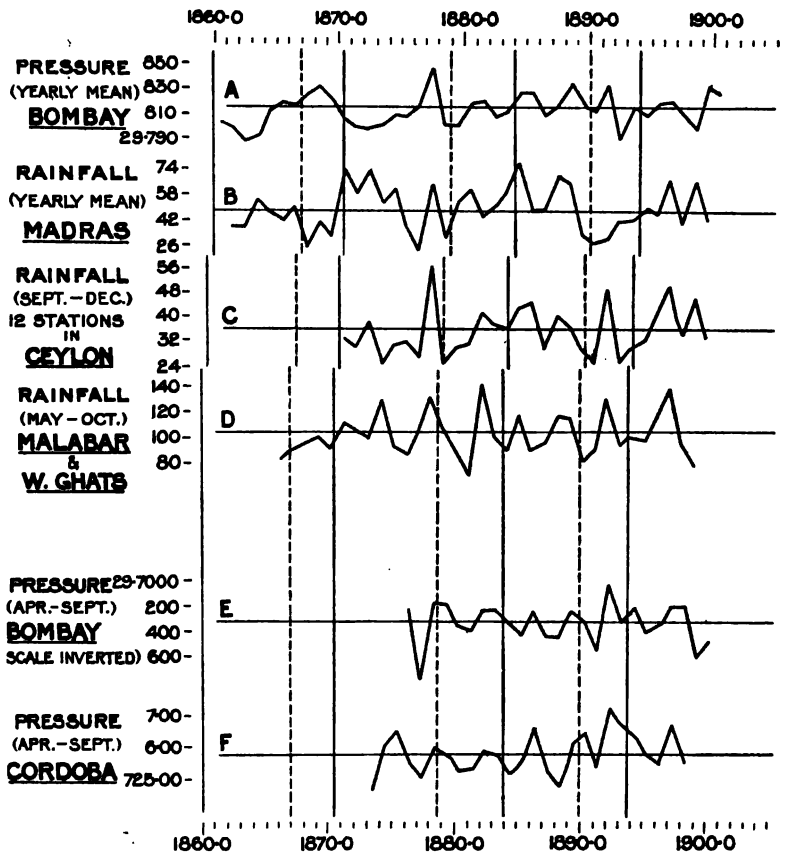


FIG. 2.

The result of this inquiry indicates that, in addition to the main epochs of maximum and minimum of prominences, which coincide in time with those of maximum and minimum of the total spotted area, there are prominent subsidiary maxima and minima having a similar short period and also coinciding in time. (Fig. 1, Curve E.)

6. Although these subsidiary prominence pulses are not distinctly duplicated in the curve representing the spotted area of the solar surface, it is to be noted that corresponding pulses are indicated in

the curves which represent the change of latitude of spotted area from year to year; and in each case an increase in prominence activity is associated with a decrease of latitude of the spotted area. (Fig. 1, Curves C and D.)

7. A comparison of these solar data with those already referred to relating to terrestrial pressures suggests that these simultaneous outbursts of prominences and changes of the latitudes in which the spots occur about every $3\frac{1}{2}$ years are the true cause of the pressure changes; and that the varying intensity of solar activity during the sunspot period of 11 years produces an effect on the pressure and circulation of our atmosphere, thus affecting the whole globe meteorologically.

8. The close correspondence between the epochs of these subsidiary pressure variations and those representing prominence frequency, suggests not only their very close relationship, but that the terrestrial pressure quickly answers to the solar changes, while so far as the work has gone it would appear that rainfall (fig. 2, Curves A, B, C, D) and snowfall are subsequent effects.

9. It may be remarked that we have already obtained evidence showing that this short-period variation is not the only one acting, but that the 11-year and 35-year periods apparently influence the short-period variations; but even this does not explain some anomalies already met with, and should the solar origin of these short-period pressure changes be subsequently confirmed, some of them not constant in all localities will have to be explained; and it is possible we may obtain in this way some new knowledge on the atmospheric circulation.

10. The period of time included in this survey begins generally with the establishment of the full records of the Indian Meteorological Department in 1875 and extends to 1895, when the regularity of the widened-line phenomena was broken, as stated in a previous communication.

ADDENDUM. Dated June 26.

In continuing the above researches we have plotted the percentage frequency of the solar prominences derived from the Italian observations for each 10° of solar latitude N. and S. of the Equator.

We find that the epochs of maximum prominence disturbance in the higher latitudes are widely different from those near the Equator. The latter are closely associated with the epochs of maximum spotted area; the former occur both N. and S. at intervening times.

We have then two sets of strongly marked prominence outbursts occurring at intervals of between 3 and 4 years.

Both sets are represented closely in the Indian pressure curves.

HARRISON AND SONS, Printers in Ordinary to His Majesty, St. Martin's Lane.

LIST OF WORKS
PRESENTED TO THE SOCIETY,
AND OF
WORKS PURCHASED WITH THE TURNOR AND HORROX FUND,
JUNE 1901 TO JUNE 1902.

An asterisk (*) indicates that the work is an excerpt.

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